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Electric Telephony.

LETTERS PATENT to William Morgan-Brown, of the Firm of Brandon and Morgan-Brown, Engineers and Patent Agents, of 38, Southampton Buildings, London, and 1, Rue Laffitte, Paris, for the Invention of "IMPROVEMENTS IN ELECTRIC TELEPHONY (TRANSMITTING OR CAUSING SOUNDS FOR TELEGRAPHING MESSAGES) AND TELEPHONIC APPARATUS." A communication from abroad by Alexander Graham Bell, of the University of Boston, Massachusetts, United States of America, Professor of Vocal Physiology."

Sealed the 15th May 1877, and dated the 9th December 1876.

PROVISIONAL SPECIFICATION left by the said William Morgan-Brown at the Office of the Commissioners of Patents on the 9th December 1876.

WILLIAM MORGAN-BROWN, of the Firm of Brandon and Morgan-Brown, Engineers and Patent Agents, of 38, Southampton Buildings, London, and 1, Rue Laffite, Paris. "IMPROVEMENTS IN ELECTRIC TELEPHONY (TRANSMITTING OR CAUSING SOUNDS FOR TELEGRAPHING MESSAGES) AND TELEPHONIC APPARATUS."

In all previous systems of telegraphy messages have been received either by means of chemical changes produced by the action of the electrical current, as in the various forms of automatic and autographical telegraphs, or by means of the mechanical movement of a portion of the receiving instrument operating to produce a visible signal, as in needle telegraphs, a mark upon paper or other material, as in printing telegraphs, or a sound, as in the Morse system. Upon these and all other plans it has been found difficult, if not impossible, to distinguish between more than four messages transmitted simultaneously over the same circuit, two in each direction.

This present Invention relates to the reproduction by the necessary receiving instruments of any particular sounds or combination of sounds through the agency of an electric current, whereby a multiplicity of telegraphic messages may be sent simultaneously over a single circuit in the same or in opposite directions and received without confusion, and whereby articulate speech may be electrically transmitted.

The first part of the Invention relates to the production or transmission of musical notes by means of intermittent impulses of votaic electricity, and to the

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utilization of such musical notes as telegraphic signals, whereby two or more telegraphic messages can be sent simultaneously in the same direction over a single circuit.

The second part of the Invention relates to the production or transmission of musical notes by means of intermittent impulses of induced electricity, whereby two or more telegraphic signals or messages can be sent simultaneously over a single circuit in the same or in opposite directions.

The third part of the Invention relates to the production or transmission of musical notes by means of undulatory currents of electricity, one battery being used for the whole circuit, whereby two or more telegraphic signals or messages can be transmitted simultaneously over a single circuit in the same or in opposite directions.

The fourth part of the Invention relates to the electrical production or transmission of sounds of every kind by means of undulatory currents of electricity, whereby not only musical sounds but articulate speech can be transmitted over a telegraph line, and two or more messages be simultaneously sent over a single circuit in the same or in opposite directions.

The fifth part of the Invention relates to the electrical production or transmission of sounds of every kind, without a battery, by means of undulatory currents of electricity, whereby not only the musical notes but articulate speech can be transmitted over a telegraph line, and two or more messages be sent simultaneously over a single circuit in the same or in opposite directions.

The sixth part of the Invention relates to the automatic reception of signals or messages by introducing at the receiving end of the line a local circuit containing a vibratory circuit breaker, whereby telephonic signals or messages may be automatically recorded.

The seventh part of the Invention relates to the application of electric telephony to autographic telegraphy, whereby characters or marks of any description may be copied in *fac simile* at the receiving end of the line.

First Plan.

The first part of the Invention (illustrated in Figures 1 and 2 of Sheet 1, and Figures 3, 4, and 5, of Sheet 2) consists of a method of and apparatus for transmitting two or more telegraphic messages or signals simultaneously along a single wire by the employment of transmitting instruments, each of which occasions a succession of electrical impulses differing in rate from the others; and of receiving instruments each tuned to a pitch at which it will be put in vibration to produce its fundamental note by one only of the transmitting instruments.

The transmitting instrument T (Figure 1) consists of an electro-magnet *e* having a steel spring armature *a*, which is kept in continuous vibration by the action of a local battery *b*; the armature *a* in the course of its vibration brings the platinum rivet *r* alternately into contact with two platinum points *l* and *m*, one, *l*, being placed in a local circuit b, s^2, e, l, r, s^3, b, and the other, *m*, communicating with the line wire W through the screw cap s^1.

The receiving instrument R, shewn in plan in Figure 1, and in elevation in Figure 2, consists of an electro-magnet E, having a coil upon only one of its legs. A steel spring armature A is firmly clamped by one extremity to the uncovered leg of the electro-magnet E, and its free end is allowed to project above the pole of the covered leg. Upon depressing the key K (Figure 1) a communication is established between the main battery B and the vibrating armature *a* of the transmitter T. When the rivet *r* touches the point *m* the main circuit is completed, the currents of *z* passed to the ground at G, and the currents of *c* pass through K, s, r, m, s^1, to the line wire W, and thence through the electro-magnet E of the receiver R to the ground at G^1. When the rivet *r* leaves the point *m*, the main circuit is broken. So long then as the key K is depressed the vibration of *a* occasions an intermittent action of the current from the battery B upon the line wire W, and the armature A of the receiver R is attracted in an intermittant manner by its electro-magnet E.

When the makes and breaks of the circuit at *m*, *r*, are timed to the normal movements of the armature A of the receiving instrument, that is, when A is tuned to yield the same musical pitch as the armature *a* of the transmitting instrument, then the armature A is thrown into strong vibration, thereby causing it to emit its musical note.

When the key K is raised the communication between the main battery B and the transmitter T is cut off, and A becomes silent. So long as the key K is depressed a musical note is emitted by A, and the duration of this note can be made to signify the dot or dash of the Morse alphabet. Thus a telegraphic despatch can be sent from T to R by manipulating the key K in the usual manner.

Figures 3, 4, and 5, Sheet 2, illustrate the combination of these instruments upon a telegraphic circuit, so as to permit of the simultaneous transmission of a number of telegraphic messages along a single wire.

The armatures of the transmitters and receivers that are numbered alike at all the stations have the same pitch. Thus the transmitter T^2 of Figure 3 is the unison of the transmitter T^2 at the station represented in Figure 4, and also of the receiver R^2 at the stations shewn in Figures 3, 4, and 5.

The sounds produced by the transmitters T, T^1, T^2, &c., differ in pitch from one another, and are so arranged that each transmitter can affect one and one only of the receiving instruments R, R^1, R^2, &c., at each station upon the line.

To illustrate the operation of this form of the Invention depress any key, say, key K^1, Figure 3, a communication being thereby established between the main battery B and the transmitting instrument T^1, an intermittent current passes on to the main line through the receiving instruments R, R^1, R^2, &c., of Figures 3, 4, and 5, to the earth at G, Figure 5. The receiving instruments R^1, Figures 3, 4, and 5, respond so long as the key K^1, Figure 3, is depressed, and become silent the moment it is raised. The other instruments R, R^2, &c., at stations Figures 3, 4, and 5, remain silent, so that a telegraphic message transmitted by the manipulation of key K^1, Figure 3, is received upon only its corresponding receiving instrument at each station toward that station herein shown as Figure 5, where the receiving instruments are connected directly with the earth.

The instruments shewn in Figure 4 operate, as just described, for those of Figure 3, the depression of each key K, K^1, or K^2, &c., operating those receiving instruments in stations 4 and 5 that are in unison with the transmitting instrument connected with the key, but does not affect the instruments in Figure 3, or in that direction.

To illustrate the simultaneous transmission of telegraphic messages by these instruments an operator in the station, shown in Figure 3, is supposed to manipulate the key K, while at the same time another operator in station Figure 4 is transmitting an entirely different despatch by the manipulation of the key K^1. The signals produced by the depression of key K, Figure 3, are received by the receivers R of Figures 3, 4, and 5, and the signals due to the manipulation of the key K^1, Figure 4, affect the receiving instrument R^1 of Figures 4 and 5, but not R^1 of Figure 3, or of any station in the direction of Figure 3, hence, although upon this plan two or more messages may be sent simultaneously over the same circuit from the same or different stations to the same or different stations, still as the signals pass only in one direction two line wires are required to complete communication in both directions. Intermittent currents adapted to work these instruments may be produced without actually making and breaking the circuit, as herein-before described, by suddenly increasing and diminishing the intensity of the current. Such currents are termed for the sake of distinction "pulsatory." Intermittent and pulsatory currents may be of two kinds, accordingly as the electrical impulses have all the same polarity, or are alternately positive and negative; in the former case they are termed "direct," in the latter "reversed" currents. These distinctions are graphically illustrated in Figures 6 and 7.

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SECOND PLAN.

In order to secure communication in both directions upon a single circuit, the second portion of this Invention was devised, and it is illustrated in Figures 8, 9, and 10. In these Figures the instruments employed are similar to those shown in Figures 1, 2, 3, 4, and 5; and like instruments are denoted by like letters, but instead of connecting the transmitting instruments T, T^1, T^2, &c., directly with the receiving instruments R, R^1, R^2, &c., as in Figures 3, 4, &c., they are connected with the primary wires of an induction coil I, of usual construction, and the currents induced in the secondary wires of the coil are directed to the receiving instruments R, R^1, R^2, &c., on the line wire. By this arrangement the receiving instruments at the terminal stations Figures 8 and 10 are connected directly with the earth at G, and signals made at any one station appear at all the stations on the circuit. On this plan therefore two or more messages may be sent simultaneously over a single circuit in the same or in opposite directions.

THIRD PLAN.

In the methods heretofore described employing intermittent currents of electricity the limit to the number of signals that can be sent simultaneously over the same wire is very speedily reached; for when a number of transmitting instruments having different rates of vibration are simultaneously making and breaking the same circuit, the effect upon the main line is practically equivalent to one continuous current; in addition to this objection local and main batteries are required at every station on the line. Similar difficulties are experienced in employing pulsatory currents; to obviate these difficulties, the plan of using an undulatory current of electricity as described in this third part of the Invention was devised.

It has long been known that when a permanent magnet is caused to approach the pole of an electro-magnet, a current of electricity is induced in the coils of the latter, and that when it is made to recede a current of opposite polarity to the first appears upon the wire. When, therefore, a permanent magnet is caused to vibrate in front of the pole of an electro-magnet, an undulatory current of electricity is induced in the coils of the electro-magnet, the undulations of which correspond in rapidity of succession to the vibrations of the magnet in polarity to the direction of its motion, and in intensity to the amplitude of its vibration, or rather to the velocity of its motion. A current of this character is graphically represented in line 3, Figure 7, Sheet 1. When the permanent magnet is caused to vibrate in front of the pole of an electro-magnet which is placed in circuit with a voltaic battery, the undulatory current induced by the vibration of the permanent magnet is superposed upon the voltaic current. When the induced impulse is of similar polarity to the voltaic current it serves to strengthen the intensity of the latter, but when it is of opposite polarity it tends to neutralize the voltaic current. In such an arrangement the resultant effect of the vibration of the permanent magnet is to throw the battery current into waves, as in line 3, Figure 6, by alternaterly increasing and diminishing the intensity of the current. Such increase and diminution in the intensity of the current does not take place with the suddenness characteristic of a pulsatory current (see line 2, Figure 6), but is proportional to the increase and diminution of the density of the air during the vibration of the inducing body.

The various kinds of electrical currents denominated intermittent, pulsatory, and undulatory, are graphically represented in Figures 6 and 7. In Figure 6 the currents are direct, that is, the electrical impulses b^2, b^2, b^2, &c., are all of the same polarity, either positive or negative, and in Figure 7 the currents are "reversed," that is, the electrical impulses are alternately positive and negative.

Direct Intermittent Current (shewn in line 1, Figure 6).—The impulses b^2, b^2, &c., are all of positive or all of negative electricity, and the vertical thickness of the lines b^2, b^2, &c., measured from the zero line z^1, z^1, represents the intensity of the current at the part observed. The horizontal extention of the line b^2 indicates the duration of the electrical impulse, and the horizontal extention of the space f^2 shews the length of time the current is absent from the circuit.

Reversed Intermittent Current (shewn in line 1, Figure 7).—Impulses of positive electricity are represented above, and impulses of negative electricity below the zero line z^1, z^1, and the impulses b^2, d^2, are respectively positive and negative, or *vice versa.*

Direct Pulsatory Current (shewn in line 2, Figure 6).—The current of electricity represented is continuous, but it changes suddenly in intensity, the elevations b^2, b^2, &c., indicating the impulses of maximum intensity, and the depressions c^2, c^2, the impulses of minimum intensity. As before, the vertical thickness of the line indicates the strength of the current.

Reversed Pulsatory Current (shewn in line 2, Figure 7).—The impulses b^2, d^2, are alternately positive and negative without any break in the continuity of the current.

Direct Undulatory Current (shewn in line 3, Figure 6).—As before, the vertical thickness of the line represents the strength of the current, the elevations b^2, b^2, &c., express the impulses of maximum intensity, and c^2, c^2, &c., those of minimum intensity. The changes of intensity, as illustrated in line 3, do not occur with the suddenness characteristic of pulsatory currents, as shewn in line 2, but are proportional to the changes in the density of the air during the production of a sound.

Reversed Undulatory Current (shewn in line 3, Figure 7).—The elevations b^2, b^2, &c., indicate impulses of positive, and the depressions d^2, d^2, impulses of negative electricity, the vertical thickness of the portions b^2, d^2, indicating the intensity of the positive or negative impulse at the part observed. The oscillations of the current above and below the zero line correspond to the increase and diminution of the density of the air during the production of a sound, hence the elevations b^2, b^2, &c., correspond to condensations of air, and the depressions d^2, d^2, &c., to rarefactions, the intensity of the positive or negative impulses being proportioned to the degree of density or rarity of the air.

The differences between intermittent pulsatory and undulatory currents will be more clearly understood by describing and illustrating the condition of the electrical current when the attempt is made to transmit two musical notes simultaneously, first upon one plan and then upon the others, let the interval between the two sounds be a major third; then their rates of vibration are in the ratio of 4 to 5. Now, when an intermittent current is used, the circuit is made and broken 4 times by the armature a, Figure 11, Sheet 1, of one transmitting instrument in the same time that 5 makes and breaks are caused by the armature a^1 of the other transmitting instrument. A^2 and B^2, Figure 11, represent the intermittent currents produced, four impulses of B^2 being made in the same time as five impulses of A^2; b^2, b^2, &c., Figure 11, shew where and for how long a time the circuit is made, and f^2, f^2, &c., indicate the duration of the breaks of the circuit. The line $A^2 + B^2$ shews the total effect upon the current when the armatures a, a^1, Figure 11, are caused simultaneously to make and break the same circuit, and the combined effect upon the current passing through the receiver R, shewn at $A^2 + B^2$, Figure 11, is very nearly equivalent to a continuos current.

When many transmitting instruments of different rates of vibration are simultaneously making and breaking the same circuit the current upon the main line become for all practical purposes continuos.

When the armatures a, a^1, are arranged upon circuit, as shewn in Figure 12, pulsatory currents traverse the coils of the receiving instrument R. The line A^2 represents the pulsatory current due to the action of one armature a; and the line B^2, the action due to the other armature a^1; b^2, b^2, &c., represent impulses of maximum intensity; and c^2, c^2, &c., impulses of minimum intensity. Four impulses of B^2 are made in the same time as five impulses of A^2. and the line $A^2 + B^2$

represents the total effect upon the current passing through the coils of the receiver R, when the armatures a and a^1 are caused to vibrate simultaneously. This effect is nearly equivalent to a continuous current of minimum intensity.

Next, consider the effect when undulatory currents are employed. Electrical undulations induced by the vibration of a body M, Figure 13, capable of inductive action, can be represented graphically by the same sinusoidal curve which expresses the vibration of the inducing body itself, for, as above stated, the rate of oscillation in the electrical current is the same as that of the inducing body. The intensity of each induced impulse is proportional to the velocity of the motion of the inducing body, and the polarity of each induced impulse depends upon the direction of the motion of the inducing body to or from the pole of its electro-magnet. The sinusoidal curves A^2 and B^2, Figure 13, represent graphically the electrical undulations induced in a circuit by the vibration of permanent magnets M and M^1 or other bodies capable of inductive action.

The portions b^2, b^2, &c., represent impulses of positive electricity; and d^2, d^2, &c., impulses of negative electricity. The horizontal line z^1, z^2, represents the zero of current, and the vertical distance of any portion of the curve b^2 or d^2 from the zero line expresses the intensity of the positive or negative impulse at the part observed.

The vibrations represented by the sinusoidal curves B^2 and A^2, Figure 13, are in the ratio aforesaid of four to five; that is, four oscillations of B^2 are made in the same line as five oscillations of A^2.

The combined effect of A^2 and B^2 when induced simultaneously on the same circuit is expressed by the curve $A^2 + B^2$, Figure 13, which is the algebraical sum of the sinusoidal curves A^2 and B^2. In Figure 14 the permanent magnets M and M^1 are caused to vibrate in front of the poles of electro-magnets e, e^1, placed in circuit with a battery B. By such an arrangement the battery current is thrown into waves. The lines A^2, B^2, represent the undulatory currents produced respectively by the vibrations of M and M^1, and as in the instances four impulses of B^2 are made in the same time as five impulses of A^2, the elevations b^2, b^2, indicate impulses of maximum intensity, and the depressions c^2, c^2, &c., impulses of minimum intensity. The vertical distance of any portion of the curve b^2, c^2, from the zero line z^1, z^1, expresses the intensity of the current at the part observed. The line $A^2 + B^2$ expresses the resultant effect upon the current when the permanent magnets M, M^1, are caused to simultaneously vibrate. The curves $A^2 + B^2$, Figures 13 and 14, also indicate the actual motion of the air when the two magnets M, M^1, are vibrated simultaneously. Thus, when electrical undulations of different rates are simultaneously produced upon the same circuit the effect is exactly analogous to that occasioned in the air by the vibration of the inducing bodies; hence the co-existence upon a telegraphic circuit of electrical undulations corresponding to sounds of different pitch is manifested, not by the obliteration of the vibratory character of the current, as with intermittent and pulsatory current, but by peculiarities in the shapes of the electrical undulations, or in other words, by peculiarities in the shapes of the curves which represent those undulations.

There are many ways of producing undulatory currents of electricity dependent for effect upon the vibration or motion of bodies capable of inductive action. A few of the methods that may be employed are as follows:—When a wire, through which a continuous current of electricity is passing, is caused to vibrate in the neighbourhood of another wire an undulatory current of electricity is induced in the latter. When a cylinder, upon which are arranged bar magnets, is made to rotate in front of the pole of an electro-magnet an undulatory current of electricity is induced in the coils of the electro-magnet.

Undulations are caused in a voltaic current by the vibration or motion of bodies capable of inductive action, or by the vibration of the conducting wire itself in the neighbourhood of such bodies. Electrical undulations may also be caused by alternately increasing and diminishing the resistance of the circuit or by alternately increasing and diminishing the power of the battery. The internal resistance of a battery is diminished by bringing the voltaic elements nearer together, and increased by placing them farther apart. The reciprocal vibration of the elements of a battery therefore occasions an undulatory action in the voltaic current.

The external resistance may also be varied; for instance, let water or some other liquid of high resistance form part of a voltaic circuit, then the more deeply the conducting wire is immersed in the water or other liquid the less resistance does the liquid offer to the passage of the current. Thence the vibration of the conducting wire in water or other liquid included in the circuit occasions undulations in the current. The vertical vibration of the elements of a battery in the liquid in which they are imursed produces an undulatory action in the current by alternately increasing and diminishing the power of the battery.

In illustration of one method of creating electrical undulations a form of apparatus is shewn in Figure 15. It is preferable to employ for this purpose an electro-magnet E, Figure 15, having a coil upon only one of its legs. A steel spring armature A is firmly clamped by one extremity to the uncovered leg *h* of the magnet, and its free end is allowed to project above the pole of the covered leg. The armature A can be set in vibration in a variety of ways, one of which is by wind, and in vibrating it produces a musical note of a certain definite pitch.

When the electro-magnet E is placed in a voltaic circuit B, E, W, E^1, B, the armature A becomes magnetic, and the polarity of its free end is opposed to that of the magnet underneath. So long as the armature A remains at rest no effect is produced upon the voltaic current, but the moment it is set in vibration to produce its musical note, a powerful inductive action takes place, and electrical undulations traverse the circuit above described. The undulatory current passing through the coil of the electro-magnet E^1 causes vibration in its armature A^1 when the armatures of the two magnets are normally in unison with one another, but the armature A^1 is unaffected by the passage of the undulatory current when the pitches of the two armatures are different.

The instruments shown in Figure 15 are like in plan to the receiving instruments R, R^1, &c., of Figures 1, 2, 3, 4, 5, 8, 9, 10. A number of instruments may be placed upon a telegraphic circuit, as in Figures 16, 17, 18. When the armature of any one of the instruments is set in vibration all the other instruments upon the circuit, which are in unison with it, respond, but those which have normally a different rate of vibration remain silent. Thus, if R, Figure 16, is set in vibration, the armature of the receivers R, Figures 17, 18, vibrate also, but all the others on the circuit remain still; so if R^1, Figure 17, is caused to emite its musical note the instruments R^1, shewn in Figures 16 and 18, respond. They continue sounding so long as the mechanical vibration of R^1, Figure 17, is continued, but becomes silent with the cessation of its motion. The duration of the sound may be used to indicate the dot or dash of the Morse alphabet, and thus a telegraphic dispatch may be indicated by alternately interrupting and renewing the sound.

When two or more instruments of different pitch are simultaneously caused to vibrate all the instruments of corresponding pitches upon the circuit are set in vibration, each responding to only that instrument used as a transmitter, with which it is in unison. Thus the signals of R, Figure 16, are repeated by R of Figures 17 and 18, but by no other instrument upon the circuit; the signals of R^1, Figure 18, by R^1, Figures 16 and 17, and the signals of R^2, Figure 17, by R^2, Figures 16 and 18, whether R, Figure 16, R^1, Figure 18, and R^2, Figure 17, are successively or simultaneously caused to vibrate. Hence by these instruments two or more telegraphic signals or messages may be sent simultaneously over the same circuit without interferring with one another, a single battery B being used for the whole circuit. These instruments may be used for the simultaneous transmission of musical notes differing in loudness as well as in pitch.

When the armature A, Figure 15, is set in vibration the armature A^1 responds not only in pitch but in loudness. Thus, when A vibrates with little amplitude a very soft musical note proceeds from A^1, and when A vibrates forcibly the amplitude of the vibration of A^1 is considerably increased and the resulting sound becomes louder; so if R and R^1, Figure 16, are sounded simultaneously (R loudly and R^1 softly) the instruments R, Figures 17 and 18, repeat loudly the signals of R, Figure 16, and R^1, Figures 17 and 18 repeat softly those of R^1, Figure 16.

FOURTH PLAN.

In the plans so far described a separate instrument is employed for every pitch, and the electrical vibrations for different pitches are combined upon the wire, each armature being capable of transmitting or receiving but a single note, and thus as many separate instruments are required as there are messages or musical notes to transmit.

In this fourth part of the Invention a single instrument is employed, the armature of which can be set in vibration by a musical instrument, or by the tones of a human voice, or by any sound whatever.

This fourth plan is represented in Figures 21, 22, and 23, wherein is shewn a single telephone at each station in place of the transmitting and receiving instruments heretofore described, the telephones being illustrated separately in Figures 19 and 20.

One of the ways in which the armature A, Figure 15, may be set in vibration has been stated to be by wind. Another mode is shewn in Figure 19, whereby motion can be imparted to the amature by the human voice, or by means of musical instrument, or by sounds of any kind.

The armature A, Figure 19, is fastened loosely by one extremity to the uncovered leg *h* of the electro-magnet E, and its other extremity is attached to the centre of a stretched membrane *n*. A cone C^2 is used to converge sound vibrations upon the membrane. When a musical note is made in the neighborhood of the membrane *n* it is set in vibration, the armature A is forced to partake of the motion, and thus electrical undulations are created upon the circuit G, B, E, W, E^1, G^1. The armature A^1 is thus thrown into synchronous vibration with the armature A, emitting a musical note of similar pitch to that which originated the vibration of armature A. If two or more musical notes be simultaneously sounded in the neighborhood of the cone C^2 the resultant motion of the air is copied by the membrane *n* to which the armature A is attached, and this armature A acting inductive by upon the current traversing the coils of the electro-magnet E occasions an increase and diminution in its utensity, and the armature A^1 is thrown into vibration by the varying attraction of the electro-magnet E^1 to which it is attached, and thus imparts to the air at n^1 a *facsimile* copy of the motion of the air that acted upon the membrane *n*; hence two or more musical notes or telegraphic messages can be sent simultaneously along a single circuit from one station to another by means of one instrument at each station.

Instead of the cone, membrane, and armature shewn in Figure 19, a plate of thin steel may be used, the vibrations of the plate in front of the magnet occasioned by the motion of the air during the production of sound changes the intensity of the current as herein-before described and occasions a similar motion in a similar steel plate in front of another electro-magnet at another station in the circuit. Such a plate is shewn in Figure 20, and marked A^3, it being attached to a frame F. The telephones shewn in Figures 21 to 26 are of the kind shewn in Figure 20. This Invention is not limited however to the use of a steel plate, but includes within its scope any materials capable of inductive action upon a current of electricity. In this plan an operator at station, Figure 21, may send a telegraphic message on a certain pitch, while another operator at another station, say, Figure 22, is transmitting another message on a different pitch, and both sounds will be audible at all the stations in the circuit.

The receiving operators will pay attention to signals of only one pitch, hence by this plan the simultaneous transmission of a number of telegraphic messages over a single circuit in the same or both directions with a single main battery for the whole circuit and a single telephonic instrument at each station is rendered possible. Whatever sound is made in the neighborhood of any telephone, say, T, *e*, Figure 21, is echoed in *facsimile* by the telephones T, *e*, of all the other stations, hence this fourth plan is also adapted for the entirely new use of transmitting intelligibly the exact sounds of articulate speech.

To convey an articulate message it is only necessary for the operator to speak in the neighborhood of a telephone, say T, *e*, Figure 21, and for the receiving operator at another instrument, say, T, *e*, Figure 23, to listen.

If two persons speak simultaneously in the neighborhood of the same or different telephones, the utterances of the two speakers are reproduced simultaneously by all the other telephones on the same circuit, hence, by this plan vocal messages may be transmitted simultaneously over the same circuit in the same or opposite directions, with one battery for the whole circuit, and one telephone at each station on the line.

In this plan of transmitting vocal utterances it is only necessary that the strength of the current should vary in intensity as the air varies in density during the utterance of the sound.

All the methods of producing undulating currents of electricity herein-before described may be employed in producing the undulations by which to transmit articulate messages. For instance, the vibrations of a membrane may cause a platinum wire to vibrate in water or other liquid of high resistance included in the circuit, and hence will occasion changes in the intensity of the current traversing the circuit proportional to the changes in the density of the air which originally gave rise to the vibrations of the membranes, and hence the sounds uttered in the neighborhood of that membrane will be reproduced from a telephone on a distant part of the circuit.

In the fifth plan of the Invention, illustrated in Figures 24, 25, and 26, the battery is omitted, and a permanent magnet M^3 is substituted for the soft iron core of the electro-magnets used in the other telephones; or the coils shown in Figures 24, 25, and 26 may be induction coils of usual construction, local batteries being placed in circuit with the primary wires so as to magnetize the soft iron cores of the coils, the unduations induce in the secondary wires by the vibration of the plates A^3 being directed upon the line wire.

The sixth plan of the Invention is represented in Figures 27, 28, and 29, Figure 27 being a side view of a receiving instrument R, having a magnet E and armature, as before described, and provided also with a vibratory circuit breaker V; this circuit breaker is designed for the purpose of enabling the armature A to open or close a local circuit through the medium of the circuit breaker V; this circuit breaker consists of a light metallic lever normally resting upon the point 5, preferably adjustable so as to close a local circuit. The extremity of the circuit breaker overhangs the free end of the armature A.

When the armature A is thrown into vibration by the action of magnet E, the circuit breaker is lifted from the point 5, and it does not return until the cessation of the vibration of the armature A.

In Figure 28 an arrangement is shewn whereby the lifting of the circuit breaker V opens a local circuit, in which is placed a Morse sounder 6 or other electrical apparatus.

In Figure 29 the circuit breaker V normally "short circuits" the battery B, cutting off the current from the Morse sounder 6, or other apparatus, so that the lifting of the circuit breaker V permits the current from the battery B to actuate the telegraphic instrument 6. The vibrating circuit breaker V may be changed in construction, it only being necessary that it have normally a slower rate of vibration than the armature A, by which it is vibrated.

Figure 30 represents an arrangement of transmitting instruments T, T^1, T^2, &c., and receiving instruments R, R^1, &c., and vibratory circuit breakers V, V^1, &c., similar to those shewn in Figures 1, 2, 27, designed to produce automatically at the receiving end of the line a *facsimile* of whatever characters or marks are presented at the transmitting end. In this plan the messages or marks to be copied may be written or printed in non-metallic ink on a metallic surface F, *o*, shown in dotted lines (preferably tinfoil), or impressed upon the same; this metallic surface is placed upon a suitable metallic support S, preferably made as a roller, having its axis at 7 connected with the battery B and the earth G. At the receiving end a similar support S^1 is connected in circuit with a battery B^1 and the vibratory circuit breakers V, V^1, V^2, &c., and on this support is placed a piece or strip of chemically prepared paper P, *a*, shewn in dotted lines.

The metallic surface F, *o*, on which is written the message to be transmitted, is moved between the support S and the ends of a series of wires 8, 9, 10, 11, 12, 13, &c., such ends being held by a non-metallic holder or bar 14. The wires 8, 9, 10, &c., communicate with the armatures *a* of transmitters T, T^1, &c., similar to the transmitter T, shewn in Figure 1. At the receiving end of the circuit the ends of a similar arrangement of wires 15, 16, 17, 18, 19, and 20 are held in place by a non-metallic holder 21, so as to rest upon the chemically prepared paper P *a*.

The metallic surface F, *o*, and the chemically prepared paper P, *a*, are each moved in the direction of the arrows under their respective series of wires, but not necessarily at equal speed, and the characters or marks on the foil are copied on the prepared paper.

When the end of any of the wires at the transmitting end, say wire 8, rests upon the metallic foil, a communication is established between the battery B and the armature *a* of the transmitter T, the platinum rivet *r*, as heretofore described, vibrates, and makes and breaks contact with the point *m*, so that an intermittent current of electricity appears upon the line wire W; so long then as the wire 8 rests on the metallic surface F, *o*, the currents of *c* pass through 7, S, F, *o*, 8, *r*, *m*, to the line wire W, and thence by branches through the receiving instruments R, R^1, &c., to the earth at G^1.

The armature of the receiving instrument R, which is in unison with the armature *a* of the transmitter T, is thrown into vibration by the passage of the intermittent current, but the armatures of the other transmitting instruments R^1, R^2, &c., having a different rate of vibration from the armature of T, do not respond.

The armature of the receiving instrument R in the course of its vibration lifts the spring lever V, breaking the circuit B^1, S^1, P, *a*, 15, V, B^1; so long then as the end of the wire 8 rests upon the metallic surface F, *o*, the local circuit in which the wire 15 is placed remains open, and thus no mark is made upon the paper P, *a*, under wire 15.

When during the movement of the metallic surface F, *o*, a portion of the non-metallic ink comes under the end of the wire 8, the connection between the battery B and transmitter T is broken, the receiver R becomes silent, the spring lever V returns to its normal position, closing the circuit above described, and a mark is made upon that part of the chemically prepared paper P, *a*, under wire 15.

Each wire 9, 10, &c., operates in a like manner to the wire 8, and the wires 16, 17, 18, &c., operate as described for wire 15.

Any of the ordinary chemically prepared paper used in connection with ordinary systems of chemical or autograph telegraphs may be used.

SPECIFICATION in pursuance of the conditions of the Letters Patent filed by the said William Morgan-Brown in the Great Seal Patent Office on the 9th June 1877.

WILLIAM MORGAN-BROWN, of the Firm of Brandon and Morgan-Brown, Engineers and Patent Agents, of 38, Southampton Buildings, London, and 1, Rue Laffitte, Paris. "IMPROVEMENTS IN ELECTRIC TELEPHONY (TRANSMITTING OR CAUSING SOUNDS FOR TELEGRAPHING MESSAGES) AND TELEPHONIC APPARATUS." A communication from abroad by Alexander Graham Bell, of the University of Boston, Massachusetts, United States of America, Professor of Vocal Physiology.

This Invention of improvements in electric telephony (transmitting or causing sounds for telegraphing messages) and telephonic apparatus relates to electric telephony and telephonic apparatus, In all previous systems of telegraphy messages have been received either by means of chemical changes produced by the action of the electrical current, as in the various forms of automatic and autographical telegraphs, or by means of the mechanical movement of a portion of the receiving instrument operating to produce a visible signal, as in needle telegraphs, a mark upon paper or other material, as in printing telegraphs, or a sound, as in the Morse system. Upon these and all other plans it has been found difficult if not impossible to distinguish between more than four messages transmitted simultaneously over the same circuit, two in each direction.

This present Invention relates to the reproduction by the necessary receiving instruments of any particular sounds or combinations of sounds through the agency of an electric current, whereby a multiplicity of telegraphic messages may be sent simultaneously over a single circuit in the same or in opposite directions, and received without confusion, and whereby articulate speech may be electrically transmitted.

The Invention relates to the production or transmission of musical notes by means of undulatory currents of electricity, one battery being used for the whole circuit, whereby two or more telegraphic signals or messages can be transmitted simultaneously over a single circuit in the same or in opposite directions.

The Invention also relates to the electrical production or transmission of sounds of every kind by means of undulatory currents of electricity, whereby not only musical sounds but articulate speech can be transmitted over a telegraph line, and two or more messages be simultaneously sent over a single circuit in the same or in opposite directions.

The Invention also relates to the electrical production or transmission of sounds of every kind without a battery by means of undulatory currents of electricity, whereby not only musical notes but articulate speech can be transmitted over a telegraph line, and two or more messages be sent simultaneously over a single circuit in the same or in opposite directions.

The Invention also relates to the automatic reception of signals or messages by introducing at the receiving end of the line a local circuit containing a vibratory circuit breaker, whereby telephonic signals or messages may be automatically recorded.

The Invention also relates to the application of electric telephony to autographic telegraphy, whereby characters or marks of any description may be copied in *facsimile* at the receiving end of the line.

FIRST PLAN.

The first method of and apparatus for transmitting two or more telegraphic messages or signals simultaneously along a single wire by the employment of transmitting instruments, each of which occasions a succession of electrical impulses differing in rate from the others, and of receiving instruments, each tuned to a pitch at which it will be put in vibration to produce its fundamental note by one only of the transmitting instruments, as devised by my communicator, is illustrated in Figures 1 and 2 of Sheet 1, and in Figures 3, 4, and 5 of Sheet 2.

The transmitting instrument T (Figure 1) consists of an electro-magnet *e* having a steel spring armature *a* which is kept in continuous vibration by the action of a local battery *b*. The armature *a* in the course of its vibration brings the platinum rivet *r* alternately into contact with two platinum points *l* and *m*, one, *l*, being placed in a local circuit *b*, s^2, *e*, *l*, *r*, s^3, *b*, and the other, *m*, communicating with the line wire W through the screw cap s^1.

The receiving instrument R, shown in plan in Figure 1, and in elevation in Figure 2, consists of an electro-magnet E having a coil upon only one of its legs. A steel spring armature A is firmly clamped by one extremity to the uncovered leg of the electro-magnet E, and its free end is allowed to project above the pole of the covered leg. Upon depressing the key K (Figure 1) a communication is established between the main battery B and the vibrating armature *a* of the transmitter T. When the rivet *r* touches the point *m* the main circuit is completed. The currents of z pass to the ground at G, and the currents of c pass through K, s, r, m, s^1, to the line wire W, and thence through the electro-magnet E of the receiver R to the ground at G^1. When the rivet r leaves the point m the main circuit is broken. So long then as the key K is depressed the vibration of a occasions an intermittent action of the current from the battery B upon the line wire W, and the armature A of the receiver R is attracted in an intermittent manner by its electro-magnet E.

When the makes and breaks of the circuit at m, r, are timed to the normal movements of the armature A of the receiving instrument, that is, when A is tuned to yield the same musical pitch as the armature a of the transmitting instrument, then the armature A is thrown into strong vibration, thereby causing it to emit its musical note.

When the key K is raised the communication between the main battery B and the transmitter T is cut off, and A becomes silent. So long as the key K is depressed a musical note is omitted by A, and the duration of this note can be made to signify the dot or dash of the Morse alphabet; thus a telegraphic despatch can be sent from T to R by manipulating the key K in the usual manner.

Figures 3, 4, and 5, Sheet 2, illustrate the combination of these instruments upon a telegraphic circuit so as to permit of the simultaneous transmission of a number of telegraphic messages along a single wire.

The armatures of the transmitters and receivers that are numbered alike at all the stations have the same pitch; thus the transmitter T^2 of Figure 3 is the unison of the transmitter T^2 at the station represented in Figure 4, and also of the receiver R^2 at the stations shown in Figures 3, 4, and 5.

The sounds produced by the transmitters T, T^1, T^2, &c., differ in pitch from one another, and are so arranged that each transmitter can affect one and one only of the receiving instruments R, R^1, R^2, &c., at each station upon the line.

To illustrate the operation of this form of the Invention depress any key, say key K^1, Figure 3. A communication being thereby established between the main battery B and the transmitting instrument T^1, an intermittent current passes on to the main line through the receiving instruments R, R^1, R^2, &c., of Figures 3, 4, and 5 to the earth at G, Figure 5. The receiving instruments R^1, Figures 3, 4, and 5, respond so long as the key K^1, Figure 3, is depressed, and become silent the moment it is raised. The other instruments R, R^2, &c., at stations Figures 3, 4, and 5 remain silent, so that a telegraphic message transmitted by the manipulation of key K^1, Figure 3, is received upon only its corresponding receiving instrument at each station toward that station herein shown as Figure 5, where the receiving instruments are connected directly with the earth.

The instruments shown in Figure 4 operate as just described for those of Figure 3, the depression of each key K, K^1, or K^2, &c., operating those receiving instruments in stations 4 and 5 that are in unison with the transmitting instrument connected with the key, but does not affect the instruments in Figure 3 or in that direction.

To illustrate the simultaneous transmission of telegraphic messages by these instruments an operator in the station, shown in Figure 3, is supposed to manipulate the key K, while at at the same time another operator in station, Figure 4, is transmitting an entirely different despatch by the manipulation of the key K^1. The signals produced by the depression of key K, Figure 3, are received by the receivers R of Figures 3, 4, and 5, and the signals due to the manipulation of the key K^1, Figure 4, affect the receiving instrument R^1 of Figures 4 and 5, but not R^1 of Figure 3, or of any station in the direction of Figure 3; hence although upon this plan two or more messages may be sent simultaneously over the same circuit from the same or different stations to the same or different stations, still as the signals pass only in one direction two line wires are required to complete communication in both directions. Intermittent currents adapted to work these instruments may be produced without actually making and breaking the circuit, as herein-before described, by suddenly increasing and diminishing the intensity of the current. Such currents are termed for the sake of distinction "pulsatory." Intermittent and pulsatory currents may be of two kinds, accordingly as the electrical impulses have all the same polarity or are alternately positive and negative. In the former case they are termed "direct," in the latter "reversed," currents. These distinctions are graphically illustrated in Figures 6 and 7.

SECOND PLAN AS DEVISED BY MY COMMUNICATOR.

In order to secure communication in both directions upon a single circuit this second plan was devised, and it is illustrated in Figures 8, 9, and 10. In these Figures the instruments employed are similar to those shown in Figures 1, 2, 3, 4, and 5, and like instruments are denoted by like letters; but instead of connecting the transmitting instruments T, T^1, T^2, &c., directly with the receiving instruments R, R^1, R^2, &c., as in Figures 3, 4, &c., they are connected with the primary wires of an induction coil I of usual construction, and the currents induced in the secondary wires of the coil are directed to the receiving instruments R, R^1, R^2, &c., on the line wire. By this arrangement the receiving instruments at the terminal stations, Figures 8 and 10, are connected directly with the earth at G, and signals made at any one station appear at all the stations on the circuit. On this plan, therefore, two or more messages may be sent simultaneously over a single circuit in the same or in opposite directions.

THIRD PLAN.

In the methods, heretofore described, employing intermittent currents of electricity the limit to the number of signals that can be sent simultaneonsly over the same wire is very speedily reached, for when a number of transmitting instruments having different rates of vibration are simultaneously making and breaking the same circuit, the effect upon the main line is practically equivalent to one continuous current. In addition to this objection, local and main batteries are required at every station on the line. Similar difficulties are experienced in employing pulsatory currents. To obviate these difficulties the plan of using an undulatory current of electricity, as described in this part of the Invention, was devised.

It has long been known that when a permanent magnet is caused to approach the pole of an electro-magnet a current of electricity is induced in the coils of the latter, and that when it is made to recede a current of opposite polarity to the first appears upon the wire. When therefore a permanent magnet is caused to vibrate in front of the pole of an electro-magnet an undulatory current of electricity is induced in the coils of the electro-magnet, the undulations of which correspond in rapidity of succession to the vibrations of the magnet, in polarity to the direction of its motion, and in intensity to the amplitude of its vibration, or rather to the velocity of its motion. A current of this character is graphically represented in line 3, Figure 7, Sheet 1. When the permanent magnet is caused to vibrate in front of the pole of an electro-magnet which is placed in circuit with a voltaic battery, the undulatory current induced by the vibration of the permanent magnet is superposed upon the voltaic current. When the induced impulse is of similar polarity to the voltaic currents it serves to strengthen the intensity of the latter, but when it is of opposite polarity it tends to neutralize the voltaic current. In such an arrangement the resultant effect of the vibration of the permanent magnet is to throw the battery currents into waves, as in line 3, Figure 6, by alternately increasing and diminishing the intensity of the current. Such increase and diminution in the intensity of the current does not take place with the suddenness characteristic of a pulsatory current (see line 2, Figure 6), but is proportional to the increase and diminution of the density of the air during the vibration of the inducing body.

The various kinds of electrical currents denominated intermittent, pulsatory, and undulatory are graphically represented in Figures 6 and 7. In Figure 6 the currents are direct, that is, the electrical impulses b^2, b^2, b^2, &c., are all of the same polarity, either positive or negative, and in Figure 7 the currents are "reversed," that is, the electrical impulses are alternately positive and negative.

Direct Intermittent Current (shown in line 1, Figure 6). The impulses b^2, b^2, &c.,

are all of positive or all of negative electricity, and the vertical thickness of the lines b^2, b^2, &c., measured from the zero line z^1, z^1, represents the intensity of the current at the part observed. The horizontal extension of the line b^2 indicates the duration of the electrical impulse, and the horizontal extension of the space f^2 shows the length of time the current is absent from the circuit.

Reversed Intermittent Current (shown in line 1, Figure 7).—Impulses of positive electricity are represented above, and impulses of negative electricity below, the zero line z^1, z^1, and the impulses b^2, d^2, are respectively positive and negative, or *vice versa*.

Direct Pulsatory Current (shown in line 2, Figure 6).—The current of electricity represented is continuous but it changes suddenly in intensity, the elevations b^2, d^2, &c., indicating the impulses of maximum intensity and the depressions c^2, c^2, the impulses of minimum intensity. As before, the vertical thickness of the line indicates the strength of the current.

Reversed Pulsatory Current (shown in line 2, Figure 7).—The impulses b^2, d^2, are alternately positive and negative without any break in the continuity of the current.

Direct Undulatory Current (shown in line 3, Figure 6).—As before, the vertical thickness of the line represents the strength of the current, the elevations b^2, b^2, &c., express the impulses of maximum intensity and c^2, c^2, &c., those of minimum intensity. The changes of intensity, as illustrated in line 3, do not occur with the suddenness characteristic of pulsatory currents, as shown in line 2, but are proportional to the changes in the density of the air during the production of a sound.

Reversed Undulatory Current (shown in line 3, Figure 7).—The elevations b^2, b^2, &c., indicate impulses of positive, and the depressions d^2, d^2, impulses of negative, electricity, the vertical thickness of the portions b^2, d^2, indicating the intensity of the positive or negative impulse at the part observed. The oscillations of the current above and below the zero line correspond to the increase and diminution of the density of the air during the production of a sound, hence the elevations b^2, b^2, &c., correspond to condensations of air and the depressions d^2, d^2, &c., to rarefactions, the intensity of the positive or negative impulses being proportioned to the degree of density or rarity of the air.

The differences between intermittent, pulsatory, and undulatory currents will be more clearly understood by describing and illustrating the condition of the electrical current when the attempt is made to transmit two musical notes simultaneously, first upon one plan and then upon the others. Let the interval between the two sounds be a major third, then their rates of vibration are in the ratio of 4 to 5. Now when an intermittent current is used the circuit is made and broken four times by the armature a, Figure 11, Sheet 1, of one transmitting instrument in the same time that five makes and breaks are caused by the armature a^1 of the other transmitting instrument; A^2 and B^2, Figure 11, represent the intermittent currents produced, four impulses of B^2 being made in the same time as five impulses of A^2; b^2, b^2, &c., Figure 11, show where and for how long time the circuit is made, and f^2, f^2, &c., indicate the duration of the breaks of the circuit. The line $A^2 + B^2$ shows the total effect upon the current when the armatures a, a^1, Figure 11, are caused simultaneously to make and break the same circuit, and the combined effect upon the current passing through the receiver R, shown at $A^2 + B^2$, Figure 11, is very nearly equivalent to a continuous current.

When many transmitting instruments of different rates of vibration are simultaneously making and breaking the same circuit the current upon the main line becomes for all practical purposes continuous.

When the armatures a, a^1, are arranged upon circuit, as shown in Figure 12, pulsatory currents traverse the coils of the receiving instrument R. The line A^2 represents the pulsatory current due to the action of one armature a, and the line B^2 the action due to the other armature a^1; b^2, b^2, &c., represent impulses of maximum intensity, and c^2, c^2, &c., impulses of minimum intensity. Four impulses of B^2 are made in the same time as five impulses of A^2, and the line $A^2 + B^2$ represents the total effect upon the current passing through the coils of the receiver R, when the armatures a and a^1 are caused to vibrate simultaneously. This effect is nearly equivalent to a continuous current of minimum intensity.

Next consider the effect when undulatory currents are employed. Electrical undulations induced by the vibration of a body M, Figure 13, capable of inductive action can be represented graphically by the same sinusoidal curve which expresses the vibration of the inducing body itself, for, as above stated, the rate of oscillation in the electrical current is the same as that of the inducing body. The intensity of each induced impulse is proportional to the velocity of the motion of the inducing body, and the polarity of each induced impulse depends upon the direction of the motion of the inducing body to or from the pole of its electro magnet. The sinusoidal curves A^2 and B^2, Figure 13, represent graphically the electrical undulations induced in a circuit by the vibration of permanent magnets M and M^1, or other bodies capable of inductive action.

The portions b^2, b^2, &c., represent impulses of positive electricity, and d^2, d^2, &c., impulses of negative electricity. The horizontal line z^1, z^1, represents the zero of current, and the vertical distance of any portion of the curve b^2 or d^2 from the zero line expresses the intensity of the positive or negative impulse at the part observed.

The vibrations represented by the sinusoidal curves B^2 and A^2, Figure 13, are in the ratio aforesaid of four to five, that is, four oscillations of B^2 are made in the same time as five oscillations of A^2. The combined effect of A^2 and B^2 when induced simultaneously on the same circuit is expressed by the curve $A^2 + B^2$, Figure 13, which is the algebraical sum of the sinusoidal curves A^2 and B^2. In Figure 14 the permanent magnets M and M^1 are caused to vibrate in front of the poles of electro-magnets e, e^1, placed in circuit with a battery B; by such an arrangement the battery current is thrown into waves. The lines A^2 and B^2 represent the undulatory currents produced respectively by the vibrations of M and M^1, and as in the other instances four impulses of B^2 are made in the same time as five impulses of A^2; the elevations b^2, b^2, &c., indicate impulses of maximum intensity, and the depressions c^2, c^2, &c., impulses of mininum intensity; the vertical distance of any portion of the curve b^2, c^2, from the zero line z^1, z^1, expresses the intensity of the current at part observed; the line $A^2 + B^2$ expresses the resultant effect upon the current when the permanent magnets M, M^1, are caused simultaneously to vibrate; the curves $A^2 + B^2$, Figures 13 and 14, also indicate the actual motion of the air when the two magnets M, M^1, are vibrated simultaneously. Thus when electrical undulations of different rates are simultaneously produced upon the same circuit the effect is exactly analogous to that occasioned in the air by the vibration of the inducing bodies. Hence the co-existence upon a telegraphic circuit of electrical undulations corresponding to sounds of different pitch is manifested not by the obliteration of the vibratory character of the current, as with intermittent and pulsatory currents, but by peculiarities in the shapes of the electrical undulations, or in other words by peculiarities in the shapes of the curves which represent those undulations.

There are many ways of producing undulatory currents of electricity dependent for effect upon the vibration or motion of bodies capable of inductive action. A few of the methods that may be employed are as follows:—When a wire through which a continuous current of electricity is passing is caused to vibrate in the neighbourhood of another wire an undulatory current of electricity is induced in the latter. When a cylinder upon which are arranged bar magnets is made to rotate in front of the pole of an electro-magnet an undulatory current of electricity is induced in the coils of the electro-magnet.

Undulations are caused in a voltaic current by the vibration or motion of bodies capable of inductive action, or by the vibration of the conducting wire itself in the neighbourhood of such bodies. Electrical undulations may also be caused by alternately increasing and diminishing the resistance of the circuit, or by alternately increasing and diminishing the power of the battery. The internal resistance of a battery is diminished by bringing the voltaic elements nearer together and increased by placing them farther apart; the reciprocal vibration of the elements of a battery therefore occasions an undulatory action in the voltaic current.

The external resistance may also be varied; for instance, let water or some other liquid of high resistance form part of a voltaic circuit, then the more deeply the conducting wire is immersed in the water or other liquid the less resistance does the liquid offer to the passage of the current; hence the vibration of the conducting wire in water or other liquid included in the circuit occasions undulations in the current. The vertical vibration of the elements of a battery in the liquid in which they are immersed produces an undulatory action in the current by alternately increasing and diminishing the power of the battery.

In illustration of one method of creating electrical undulations a form of apparatus is shown in Figure 15. It is preferable to employ for this purpose an electro-magnet E, Figure 15, having a coil upon only one of its legs. A steel spring armature A is firmly clamped by one extremity to the uncovered leg *h* of the magnet, and its free end is allowed to project above the pole of the covered leg. The armature A can be set in vibration in a variety of ways, one of which is by wind, and in vibrating it produces a musical note of a certain definite pitch.

When the electro-magnet E is placed in a voltaic circuit B, E, W, E^1, B, the armature A becomes magnetic, and the polarity of its free end is opposed to that of the magnet underneath. So long as the armature A remains at rest no effect is produced upon the voltaic current, but the moment it is set in vibration to produce its musical note a powerful inductive action takes place and electrical undulations traverse the circuit above described. The undulatory current passing through the coil of the electro-magnet E^1 causes vibration in its armature A^1 when the armatures of the two magnets are normally in unison with one another, but the armature A^1 is unaffected by the passage of the undulatory current when the pitches of the two armatures are different.

The instruments shown in Figure 15 are like in plan to the receiving instruments R, R^1, &c., of Figures 1, 2, 3, 4, 5, 8, 9, 10. A number of instruments may be placed upon a telegraphic circuit, as in Figures 16, 17, 18. When the armature of any one of the instruments is set in vibration all the other instruments upon the circuit which are in unison with it respond, but those which have normally a different rate of vibration remain silent. Thus if R, Figure 16, is set in vibration the armatures of the receivers R, Figure 17, 18, vibrate also, but all the others on the circuit remain still. So if R^1, Figure 17, is caused to emit its musical note the instruments R^1, shown in Figures 16 and 18, respond. They continue sounding so long as the mechanical vibration of R^1, Figure 17, is continued, but become silent with the cessation of its motion. The duration of the sound may be used to indicate the dot or dash of the Morse alphabet, and thus a telegraphic dispatch may be indicated by alternately interrupting and renewing the sound.

When two or more instruments of different pitch are simultaneously caused to vibrate, all the instruments of corresponding pitches upon the circuit are set in vibration, each responding to only that instrument used as a transmitter with which it is in unison. Thus the signals of R, Figure 16, are repeated by R of Figures 17 and 18, but by no other instrument upon the circuit. The signals of R^1, Figure 18, by R^1, Figures 16 and 17, and the signals of R^2, Figure 17, by R^2, Figures 16 and 18, whether R, Figure 16, R^1, Figure 18, and R^2, Figure 17, are successively or simultaneously caused to vibrate. Hence by these instruments two or more telegraphic signals or messages may be sent simultaneously over the same circuit without interfering with one another, a single battery B being used for the whole circuit. These instruments may be used for the simultaneous transmission of musical notes differing in loudness as well as in pitch.

When the armature A, Figure 15, is set in vibration the armature A^1 responds not only in pitch but in loudness. Thus when A vibrates with little amplitude a very soft musical note proceeds from A^1, and when A vibrates forcibly the amplitude of the vibration of A^1 is considerably increased, and the resulting sound becomes louder. So if R and R^1, Figure 16, are sounded simultaneously (R loudly and R^1 softly), the instruments R, Figures 17 and 18, repeat loudly the signals of R, Figure 16, and R^1, Figures 17 and 18 repeat softly those of R^1, Figure 16.

FOURTH PLAN.

In the plans so far described a separate instrument is employed for every pitch, and the electrical vibrations for different pitches are combined upon the wire, each armature being capable of transmitting or receiving but a single note, and thus as many separate instruments are required as there are messages or musical notes to transmit.

In this fourth part of the Invention a single instrument is employed, the armature of which can be set in vibration by a musical instrument or by the tones of the human voice, or by any sound whatever.

This fourth plan is represented in Figures 21, 22, and 23, wherein is shown a single telephone at each station in place of the transmitting and receiving instruments heretofore described, the telephones being illustrated separately in Figures 19 and 20.

One of the ways in which the armature A, Figure 15, may be set in vibration has been stated to be by wind. Another mode is shown in Figure 19, whereby motion can be imparted to the armature by the human voice, or by means of a musical instrument, or by sounds of any kind.

The armature A, Figure 19, is fastened loosely by one extremity to the uncovered leg *h* of the electro-magnet E, and its other extremity is attached to the centre of a stretched membrane *n*. A cone C^2 is used to converge sound vibrations upon the membrane. When a musical note is made in the neighbourhood of the membrane *n* it is set in vibration, the armature A is forced to partake of the motion, and thus electrical undulations are created upon the circuit G, B, E, W, E^1, G^1. The armature A^1 is thus thrown into synchronous vibration with the armature A, emitting a musical note of similar pitch to that which originated the vibration of armature A. If two or more musical notes be simultaneously sounded in the neighbourhood of the cone C^2, the resultant motion of the air is copied by the membrane *n* to which the armature A is attached, and this armature A, acting inductively upon the current traversing the coils of the electro-magnet E, occasions an increase and diminution in its intensity, and the armature A^1 is thrown into vibration by the varying attraction of the electro-magnet E^1 to which it is attached, and thus imparts to the air at n^1 a *facsimile* copy of the motion of the air that acted upon the membrane *n*, hence two or more musical notes or telegraphic messages can be sent simultaneously along a single circuit from one station to another by means of one instrument at each station.

Instead of the cone membrane and armature shown in Figure 19 a plate of thin steel may be used; the vibrations of the plate in front of the magnet occasioned by the motion of the air during the production of sound changes the intensity of the current as herein-before described, and occasions a similar motion in a similar steel plate in front of another electro-magnet at another station in the circuit. Such a plate is shown in Figure 20 and marked A^3, it being attached to a frame F. The telephones shown in Figures 21 to 26 are of the kind shown in Figure 20. This Invention is not limited however to the use of a steel plate, but includes within its scope any material capable of inductive action upon a current of electricity. In this plan an operator at station Figure 21 may send a telegraphic message on a certain pitch, while another operator at another station, say, Figure 22, is transmitting another message on a different pitch, and both sounds will be audible at all the stations in the circuit.

The receiving operators will pay attention to signals of only one pitch, hence by this plan the simultaneous transmission of a number of telegraphic messages over a single circuit in the same or both directions with a single main battery for the whole circuit, and a single telephonic instrument at each station, is rendered possible.

Whatever sound is made in the neighbourhood of any telephone, say, T, *e*, Figure 21, is echoed in *facsimile* by the telephones T, *e*, of all the other stations, hence this fourth plan is also adapted for the entirely new use of transmitting intelligibly the exact sounds of articulate speech.

To convey an articulate message it its only necessary for the operator to speak in the neighbourhood of a telephone, say T, *e*, Figure 21, and for the receiving operator at another instrument, say T, *e*, Figure 23, to listen.

If two persons speak simultaneously in the neighbourhood of the same or different telephones, the utterances of the two speakers are reproduced simultaneously by all the other telephones on the same circuit; hence by this plan, vocal messages may be transmitted simultaneously over the same circuit in the same or opposite directions with one battery for the whole circuit and one telephone at each station on the line. In this plan of transmitting vocal utterance it is only necessary that the strength of the current should vary in intensity as the air varies in density during the utterance of the sound.

All the methods of producing undulatory currents of electricity herein-before described may be employed in producing the undulations by which to transmit articulate messages. For instance the vibrations of a membrane may cause a platinum wire to vibrate in water or other liquid of high resistance included in the circuit, and hence will occasion changes in the intensity of the current traversing the circuit proportional to the changes in the density of the air which originally gave rise to the vibrations of the membrane, and hence the sounds uttered in the neighbourhood of that membrane will be reproduced from a telephone on a distant part of the circuit.

In the fifth plan of the Invention, illustrated in Figures 24, 25, and 26, the battery is omitted and a permanent magnet M^3 is substituted for the soft iron core of the electro-magnets used in the other telephones. Or the coils shown in Figures 24, 25, and 26, may be induction coils of usual construction, local batteries being placed in circuit with the primary wires so as to magnetize the soft iron cores of the coils. The undulations induced in the secondary wires by the vibration of the plates A^3 being directed upon the line wire.

The sixth plan of the Invention is represented in Figures 27, 28, and 29, Figure 27 being a side view of a receiving instrument R having a magnet E and armature A as before described, and provided also with a vibratory circuit breaker V. This circuit breaker is designed for the purpose of enabling the armature A to open or close a local circuit through the medium of the circuit breaker V. This circuit breaker consists of a light metallic lever normally resting upon the point 5, preferably adjustable, so as to close a local circuit. The extremity of the circuit breaker overhangs the free end of the armature A. When the armature A is thrown into vibration by the action of magnet E, the circuit breaker is lifted from the point 5, and it does not return until the cessation of the vibration of the armature A.

In Figure 28 an arrangement is shown whereby the lifting of the circuit breaker V opens a local circuit in which is placed a Morse sounder 6 or other electrical apparatus.

In Figure 29 the circuit breaker V normally "short circuits" the battery B, cutting off the current from the Morse sounder 6 or other apparatus, so that the lifting of the circuit breaker V permits the current from the battery B to actuate telegraphic instrument 6. The vibrating circuit breaker V may be changed in construction, it only being necessary that it have normally a slower rate of vibration than the armature A by which it is vibrated.

Figure 30 represents an arrangement of transmitting instruments T, T^1, T^2, &c., and receiving instruments R, R^1, &c., and vibratory circuit breakers V, V^1, &c., similar to those shown in Figures 1, 2, 27, designed to produce automatically at the receiving end of the line a *facsimile* of whatever characters or marks are presented at the transmitting end. In this plan the messages or marks to be copied may be written or printed in non-metallic ink on a metallic surface F, *o*, shown in dotted lines (preferably tin foil) or impressed upon the same. This metallic surface is placed upon a suitable metallic support S preferably made as a roller, having its axis at 7 connected with the battery B and the earth G. At the receiving end a similar support S^1 is connected in circuit with a battery B^1 and the vibratory circuit breakers V, V^1, V^2, &c., and on this support is placed a piece or strip of chemically prepared paper P, *a*, shown in dotted lines.

The metallic surface F, *o*, on which is written the message to be transmitted, is moved between the support S and the ends of a series of wires 8, 9, 10, 11, 12, 13, &c., such ends being held by a non-metallic holder or bar 14. The wires 8, 9, 10, &c., communicate with the armatures *a* of transmitters T, T^1, &c., similar to the transmitter T shown in Figure 1.

At the receiving end of the circuit the ends of a similar arrangement of wires 15, 16, 17, 18, 19, and 20, are held in place by a non-metallic holder 21, so as to rest upon the chemically prepared paper P, *a*.

The metallic surface F, *o*, and the chemically prepared paper P, *a*, are each moved in the direction of the arrows under their respective series of wires, but not necessarily at equal speed, and the characters or marks on the foil are copied on the prepared paper.

When the end of any of the wires at the transmitting end, say wire 8, rests upon the metallic foil a communication is established between the battery B and the armature *a* of the transmitter T; the platinum rivet *r*, as heretofore described, vibrates and makes and breaks contact with the point *m*, so that an intermittent current of electricity appears upon the line wire W. So long then as the wire 8 rests on the metallic surface F, *o*, the currents of *c* pass through 7, S, F, *o*, 8, *r*, *m*, to the line wire W, and thence by branches through the receiving instruments R, R^1, &c., to the earth at G^1.

The armature of the receiving instrument R, which is in unison with the armature *a* of the transmitter T, is thrown into vibration by the passage of the intermittent current, but the armatures of the other transmitting instruments R^1, R^2, &c., having a different rate of vibration from the armature of T do not respond.

The armature of the receiving instrument R in the course of its vibration lifts the spring lever V, breaking the circuit B^1, S^1, P, *a*, 15, V, B^1. So long then as the end of the wire 8 rests upon the metallic surface F, *o*, the local circuit in which the wire 15 is placed remains open, and thus no mark is made upon the paper P, *a*, under wire 15.

When during the movement of the metallic surface F, *o*, a portion of the non-metallic ink comes under the end of the wire 8, the connection between the battery B and transmitter T is broken, the receiver R becomes silent, the spring lever V returns to its normal position, closing the circuit above described, and a mark is made upon that part of the chemically prepared paper P, *a*, under wire 15.

Each wire 9, 10, &c., operates in a like manner to the wire 8, and the wires 16, 17, 18, &c., operate as described for wire 15.

Any of the ordinary chemically prepared paper used in connection with ordinary systems of chemical or autograph telegraphs may be used.

Referring again to the fifth plan, the magnet may be of the horse-shoe form as shown at 24 in Figure 31; and the coils of insulated wire 25 may surround soft iron cores or pole pieces 26, screwed or otherwise fastened to the ends of the magnet 24. The cores or pole pieces are placed near the face of the metallic plate A^3, it being attached to a cup-shaped block 28, having a central orifice 29 for the reception of a speaking or hearing tube to convey sounds to or from the plate A^3. The magnet is attached to a stud 30 adapted to be moved in suitable grooves in the base 31 by means of a screw 32 having its end connected with the stand, the body of the screw being fitted to turn in a screw threaded stud. The movements of the screw are just the distance between the pole of the magnet and the plate A^3, and permit the poles to be placed almost in contact with the plate.

The coils may be placed about the ends of the magnet 24, and the soft iron pole pieces be omitted.

Figure 32 represents in perspective a telephone of the kind shown in Figure 31 when placed within a sounding box 33. The coils will preferably be very thin, and be placed at the extremity or extremities of the magnet. One, two, or more magnetic poles with coils may be placed near a plate to intensify the effect.

The soft iron core and coil may be attached to the plate instead of the magnet, or the core may be placed upon the plate, and the coil on the magnet, or *vice versa*. The magnet may be made to vibrate instead of the plate.

Having now described and particularly set forth the nature of the said Invention, and the manner of carrying the same into effect, I would have it understood that what I claim is,—

First. The method herein described of producing or transmitting musical notes by means of undulatory currents of electricity, whereby two or more telegraphic signals or messages can be transmitted simultaneously over a single circuit in the same or opposite directions.

Second. In a system of multiple telegraphy wherein undulatory currents of electricity are employed, the employment of receiving instruments, the armatures of which are tuned to definite pitches so as to vibrate only when a sound of like pitch is transmitted, substantially as described.

Third. A system of telegraphy in which the receiver is set in vibration by the employment of undulatory currents of electricity, substantially as set forth.

Fourth. The combination, substantially as set forth, of a permanent magnet or other body capable of inductive action with a closed circuit, so that the vibration of the one shall occasion electrical undulations in the other or in itself, and this I claim whether the permanent magnet be set in vibration in the neighbourhood of the conducting wire forming the circuit, or whether the conducting wire be set in vibration in the neighbourhood of the permanent magnet, or whether the conducting wire and the permanent magnet, both simultaneously, be set in vibration in each other's neighbourhood.

Fifth. The method of producing undulations in a continuous voltaic current by the vibration or motion of bodies capable of inductive action, or by the vibration or motion of the conducting wire itself in the neighbourhood of such bodies, as set forth.

Sixth. The method of producing undulations in a continuous voltaic circuit by gradually increasing and diminishing the resistance of the circuit, or by gradually increasing and diminishing the power of the battery, as set forth.

Seventh. The method of transmitting vocal or other sounds electrically by causing the intensity of an electrical current to vary in a manner proportional to the variations of density produced in the air by the said sounds.

Eighth. The method of transmitting vocal or other sounds electrically by causing the intensity and polarity of an electrical current to vary in a manner proportional to the velocity and the direction of motion of the particles of air during the production of the sounds.

Ninth. The union upon and by means of an electric circuit of two or more telephones constructed for operation substantially as described, so that if the plate armatures of any one of the said instruments be moved in any manner the armatures of all the other telephones upon the same circuit will be moved in like manner, and if the transmitter armature be moved or vibrated by sound like sounds will be produced by the motion or vibration of the armature of the other telephones upon the circuit.

Tenth. In a system of electric telegraph or telephony, consisting of transmitting and receiving instruments united uponan electric circuit I claim the production in the armature of each receiving instrument of any given motion by subjecting said armature to an attraction varying in intensity, however such variation may be produced in the magnet, and hence I claim the production of any given sound or sounds from the armature of the receiving instrument by subjecting said armatureto an attraction varying in intensity in such manner as to throw the armature into that form of vibration which characterizes the given sound or sounds.

Eleventh. The combination with an electro-magnet of a plate of iron or steel or other material capable of inductive action which can be thrown into vibration by the movement of surrounding air, or by the attraction of a magnet.

Twelfth. In combination with a plate and electro-magnet, as before claimed, the means herein described or their mechanical equivalents of adjusting the relative position of the two, so that without touching they may be set as closely together as possible.

Thirteenth. In an electric telephone the combination with the plate of a magnet having coils upon the end or ends of the magnet nearest the plate, substantially as described.

Fourteenth. The combination with an electric telephone, such as described, of a sounding box, substantially as herein shown and set forth.

Fifteenth. In combination with an electric telephone, as herein described, the employment of a speaking or hearing tube for conveying sounds to or from the telephone, substantially as set forth.

Sixteenth. In an electric telephone the combination with a permanent magnet and plate armature of a soft iron pole piece forming the core for the coil, substantially as described.

Seventeenth. In a system of telegraphy in which the vibrating receiver operates the circuit breaker of a local circuit independent of said receiver, as described, a vibratory circuit breaker for said local circuit, consisting of a light spring arm, whose free end overlaps the reed or vibrating portion of the receiver in combination with a portion of the receiver in combination with a contact tip or point in said circuit with which the spring arm makes and breaks contact, substantially as set forth.

Eighteenth. The autograph telegraph comprising the combination of a series of transmitters and transmitting bristles or wires, a single main wire receivers corresponding in number to the transmitters, tuned to a pitch to vibrate in unison with the succession of electric impulses transmitted from their respective transmitters, vibratory circuit breakers, one for each receiver, and a local circuit and receiving bristle for each vibratory circuit breaker, the series of bristles resting upon prepared paper, the whole for operation substantially as shown and described.

In witness whereof, I, the said William Morgan-Brown, have hereunto set my hand and seal, this Sixth day of June, in the year of our Lord One thousand eight hundred and seventy-seven.

WILLIAM MORGAN-BROWN. (L.S.)

LONDON: Printed by George Edward Eyre and William Spottiswoode,
Printers to the Queen's most Excellent Majesty. 1877.

A.D. 1876. Dec. 9. No 4765.
MORGAN-BROWN'S Provisional Specification.

(2 SHEETS)
SHEET 1

FIG. 1.

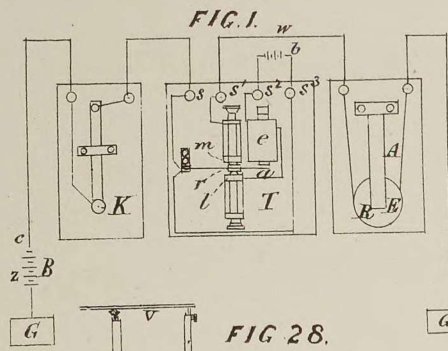


FIG. 2.

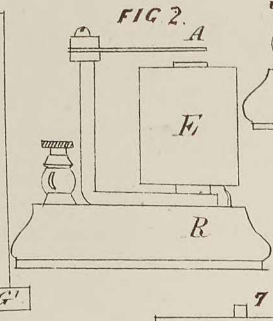


FIG. 27

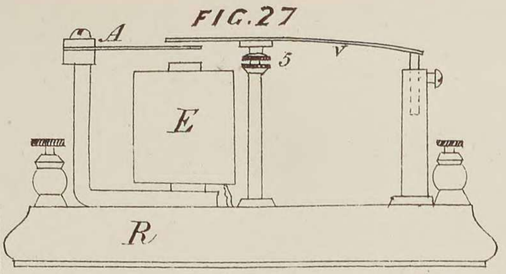
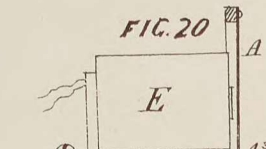


FIG. 20



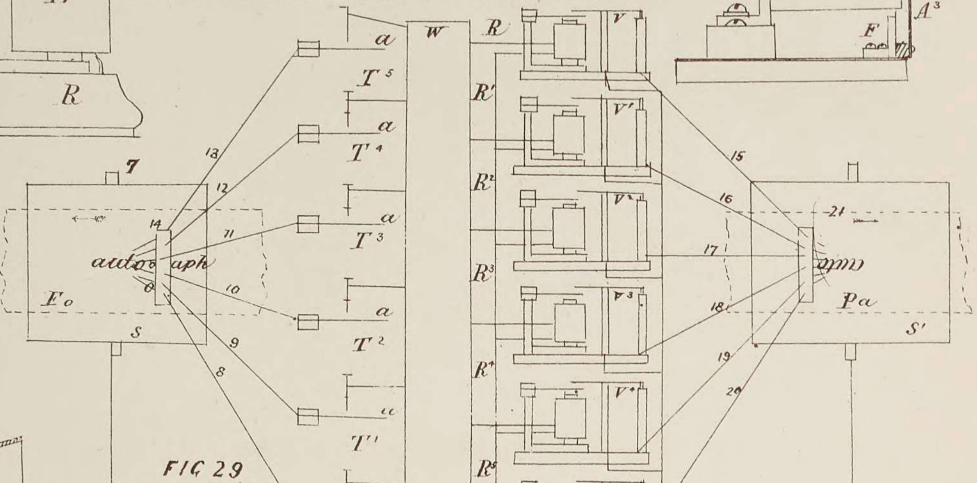


FIG. 28.

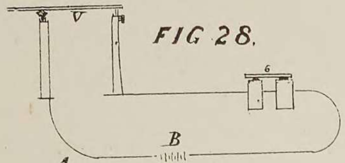
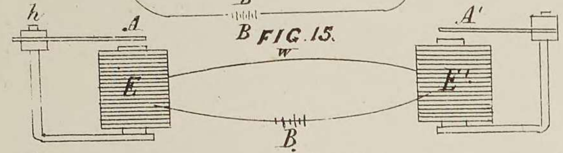


FIG. 15.



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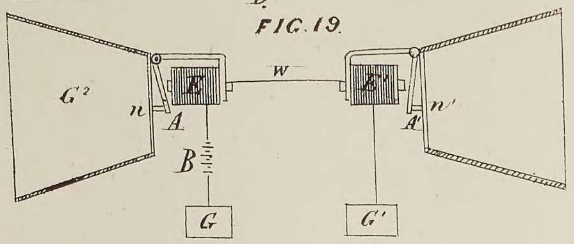


FIG. 29

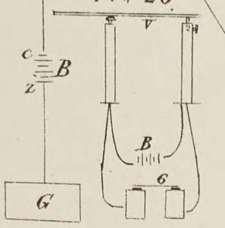


FIG. 6.
Direct

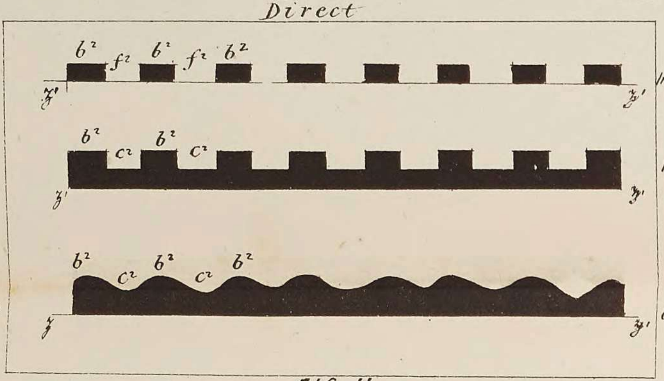


FIG. 7. Reversed

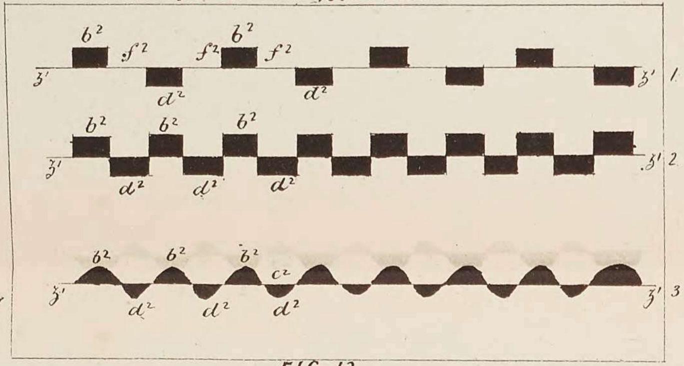


FIG. 11.

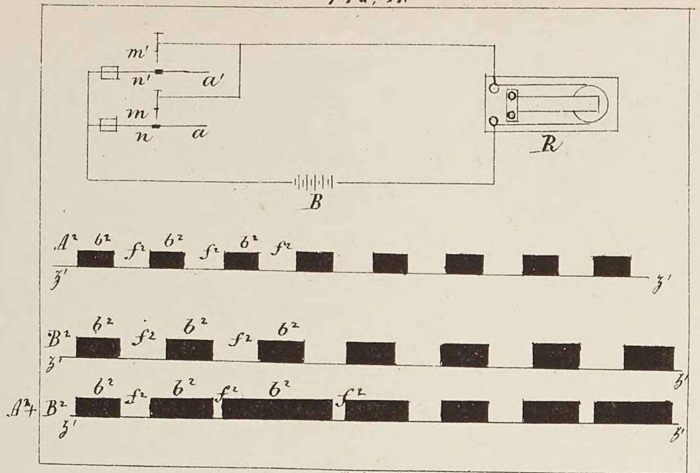


FIG. 12

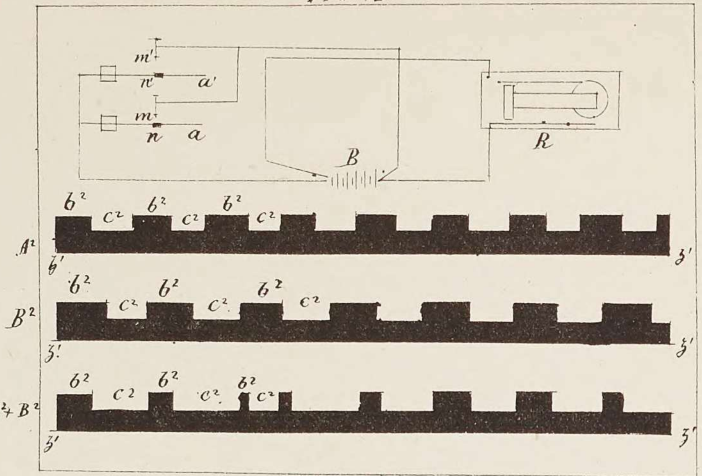


FIG. 13.

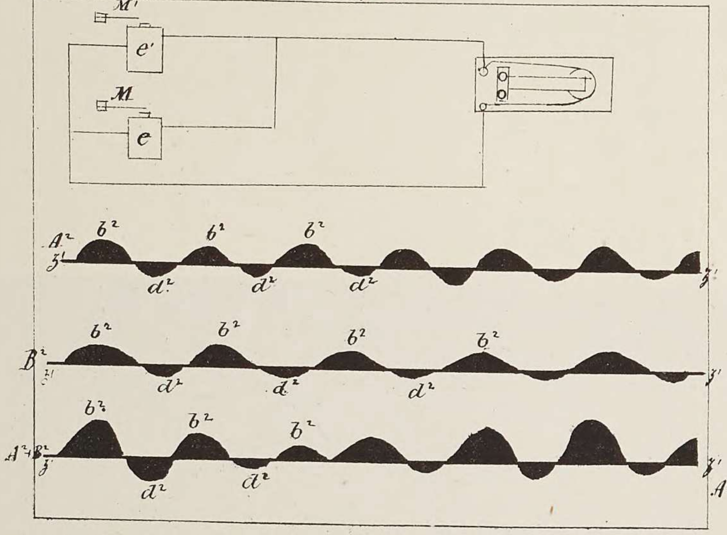
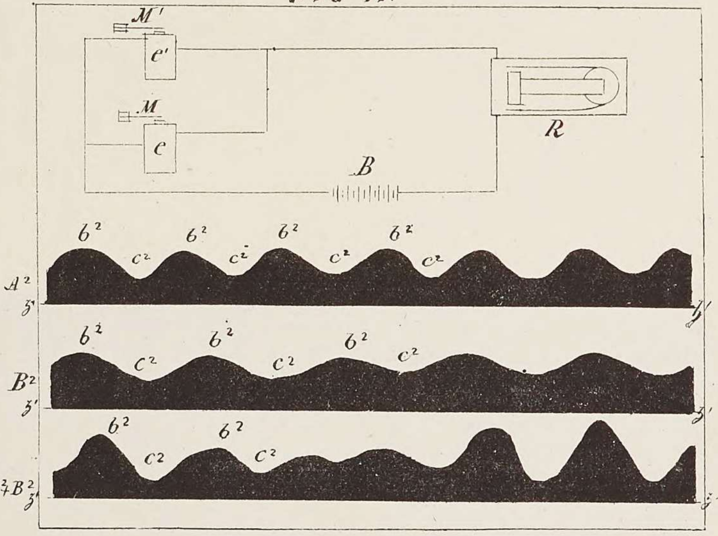


FIG. 14.



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MORGAN-BROWN'S Provisional Specification.

(2 SHEETS)
SHEET 2.

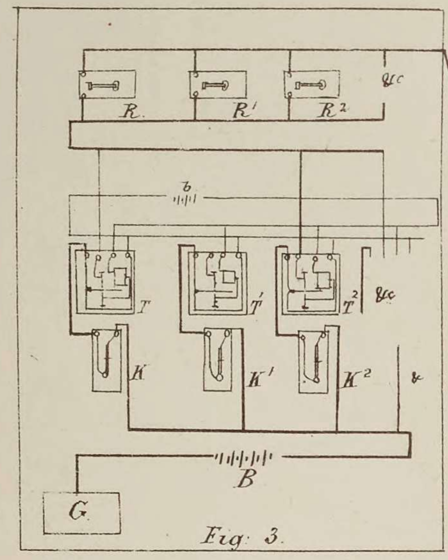
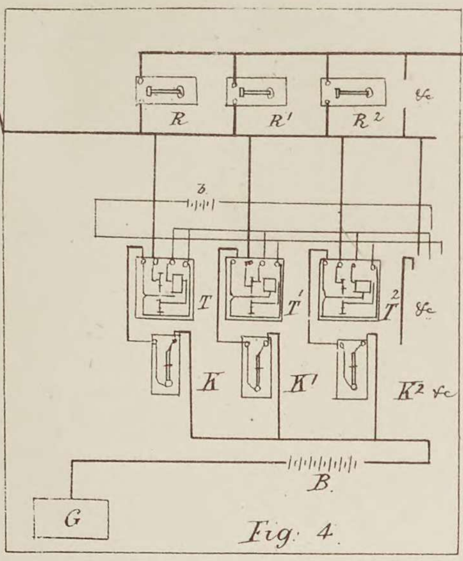


Fig: 3.



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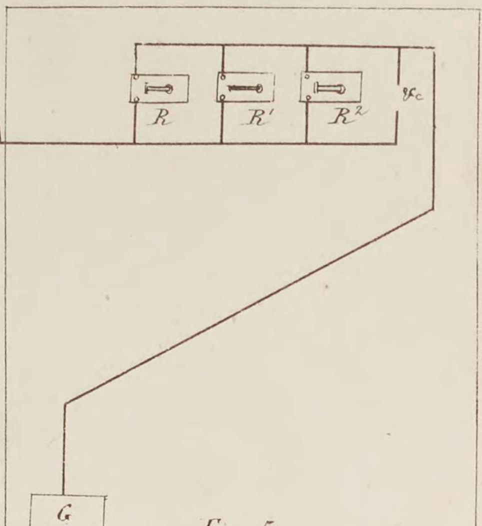


Fig: 5

First Plan.

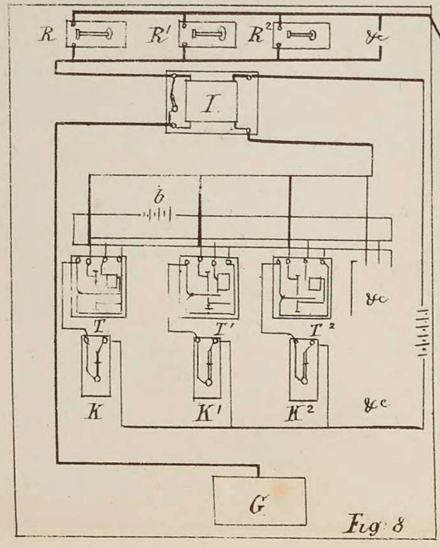


Fig: 8

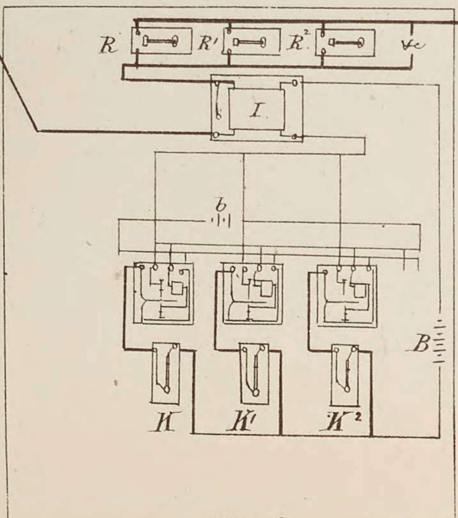


Fig: 9.

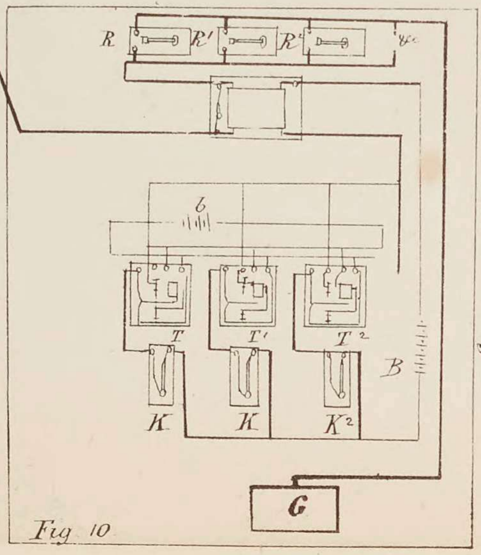


Fig 10

Second Plan

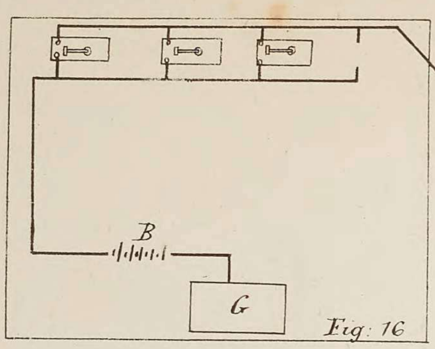


Fig: 16

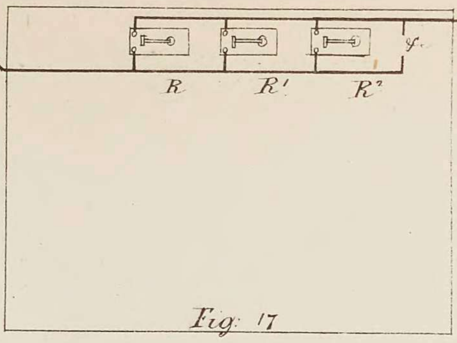


Fig: 17

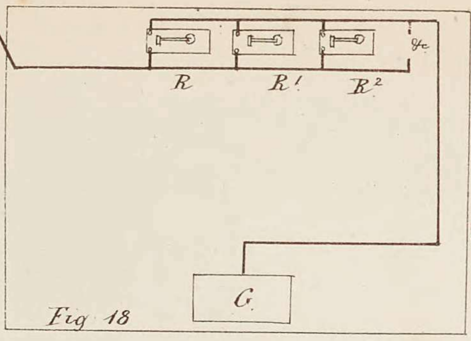


Fig 18

Third Plan

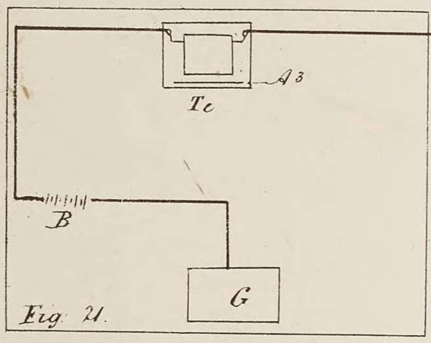


Fig: 21.

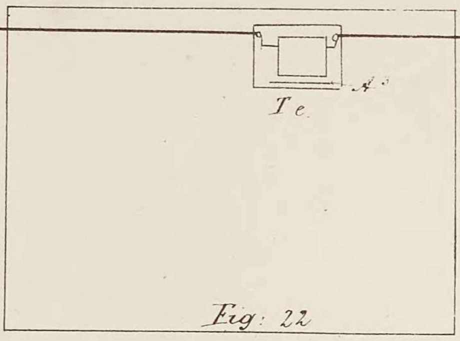


Fig: 22

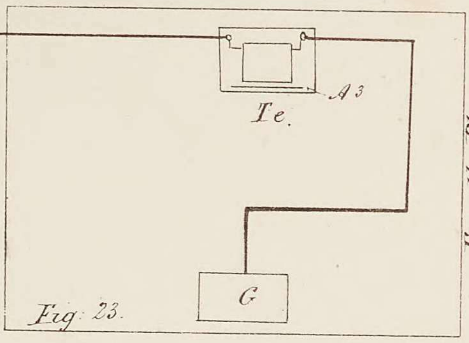


Fig: 23.

Fourth Plan.

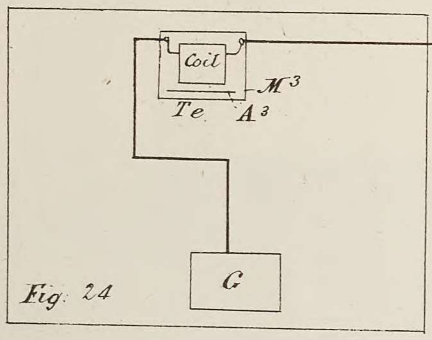
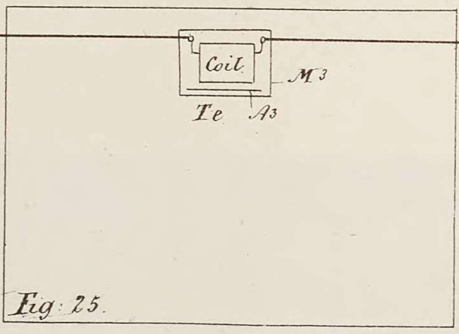


Fig: 24



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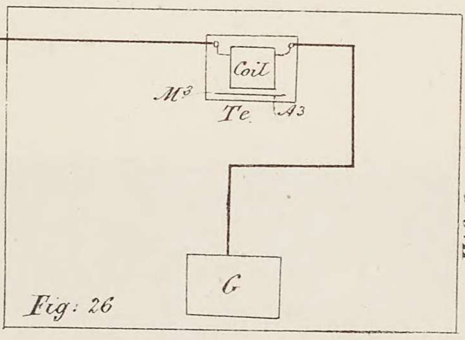

Fig: 26

Fifth Plan.

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MORGAN-BROWN'S SPECIFICATION.

(3 SHEETS)
SHEET 1.

Fig. 1.

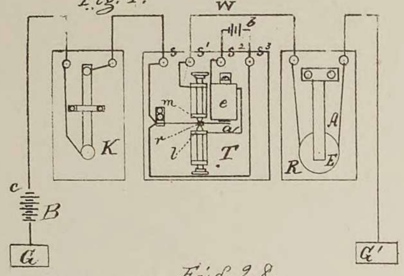


Fig. 2.

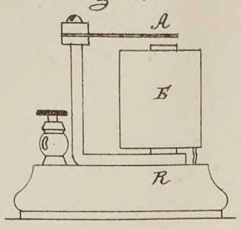


Fig. 27.

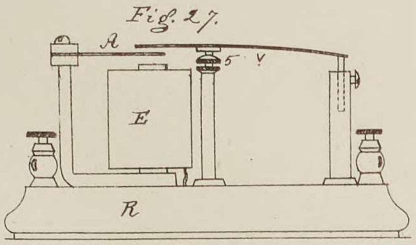


Fig. 20.

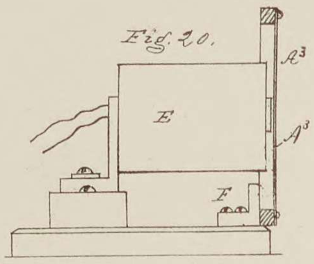


Fig. 28.

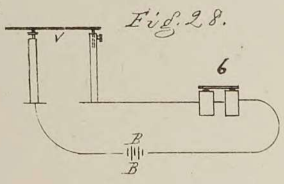


Fig. 29.

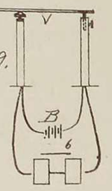


Fig. 15.

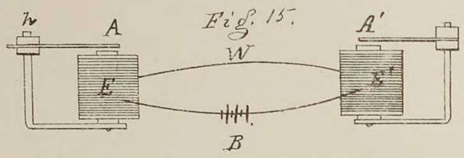


Fig. 19.

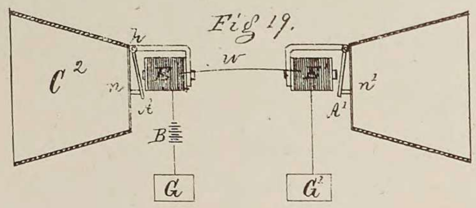


Fig. 30.

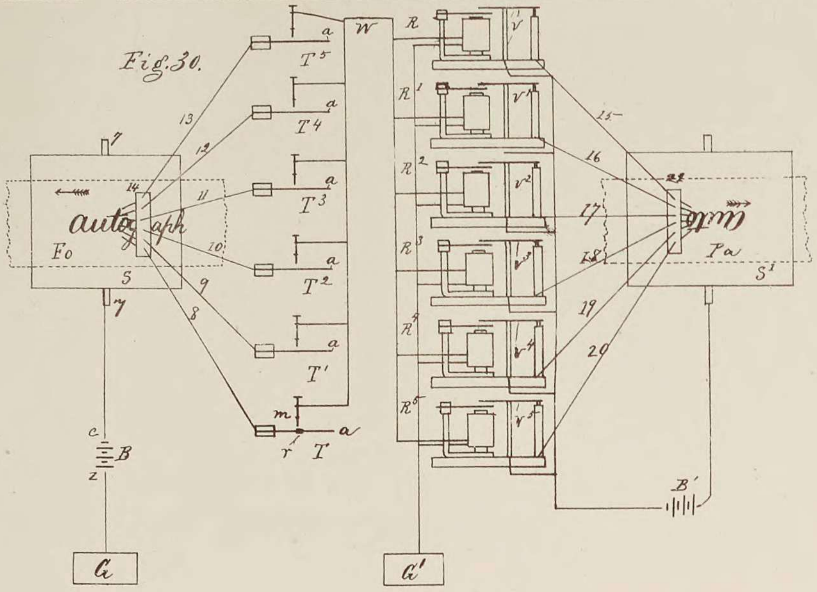


Fig. 6.
Direct

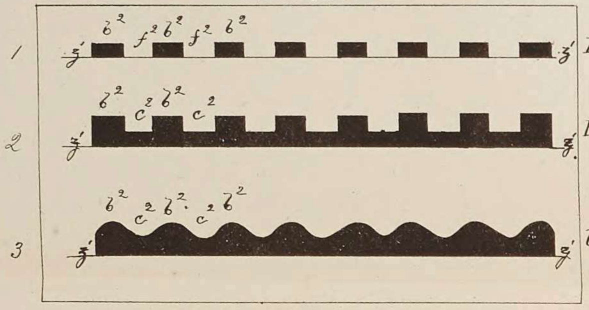


Fig. 7.
Reversed

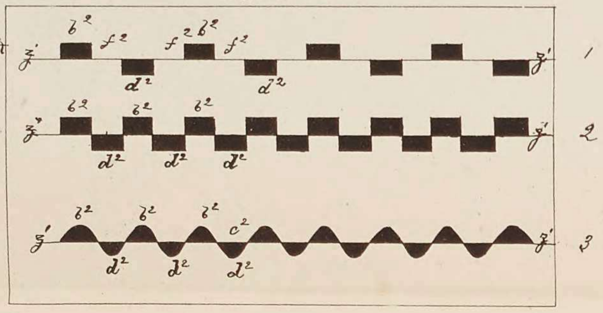
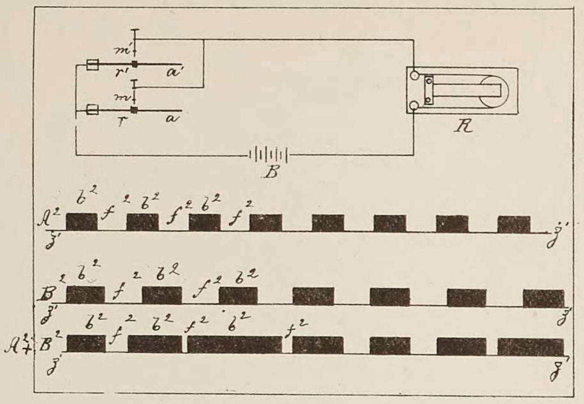


Fig. 11.



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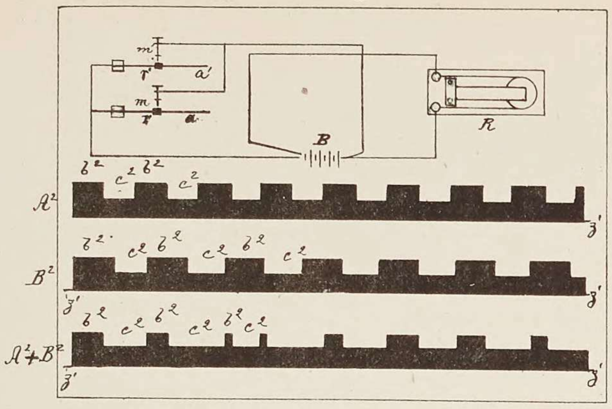

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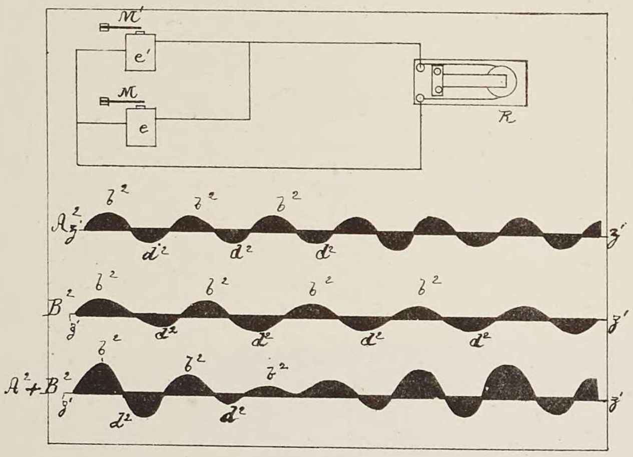

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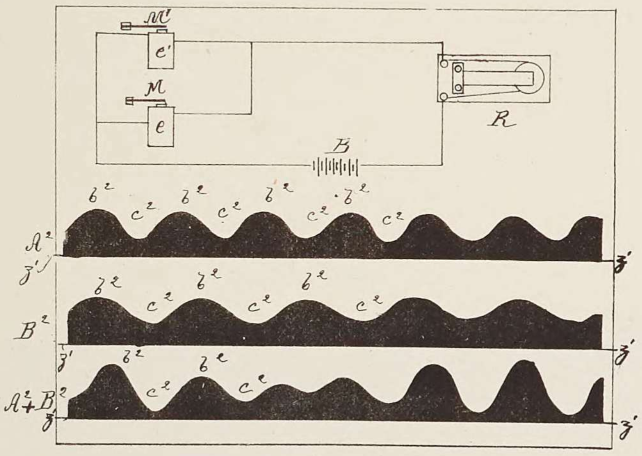

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MORGAN-BROWN'S Specification.

(3 SHEETS)
SHEET 2.

First Plan

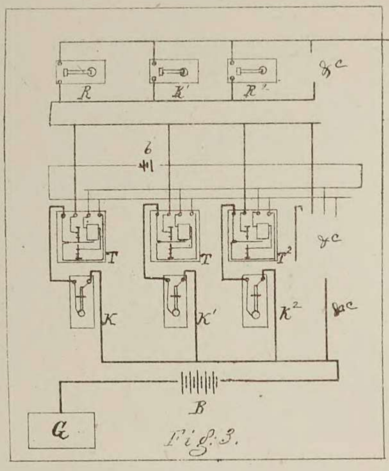


Fig. 3.

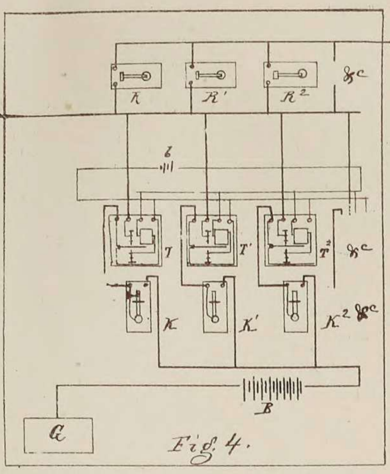


Fig. 4.

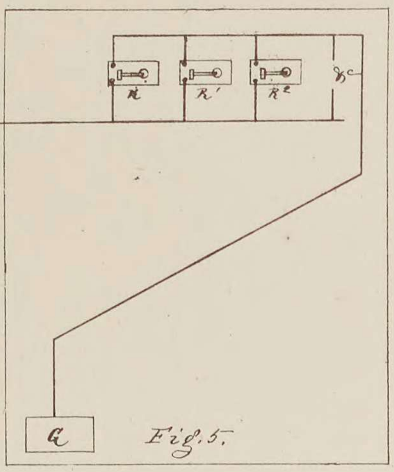
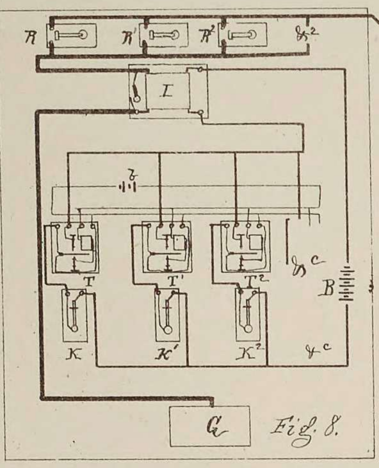


Fig. 5.

Second Plan



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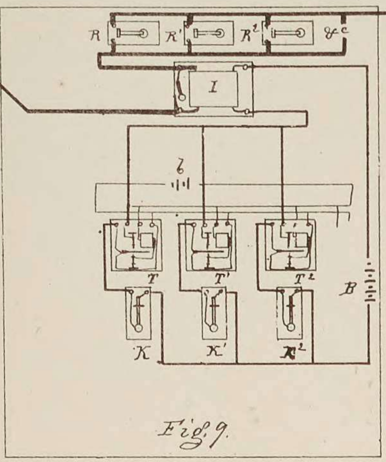

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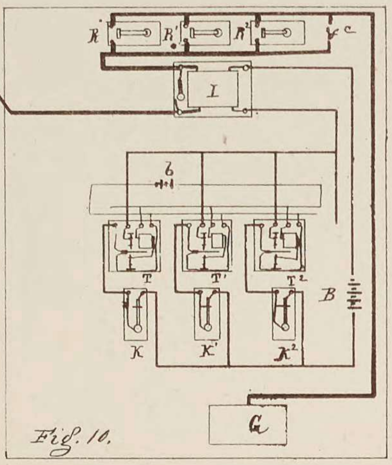


Fig. 10.

Third Plan

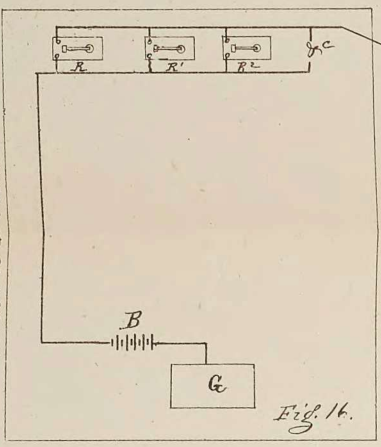


Fig. 16.

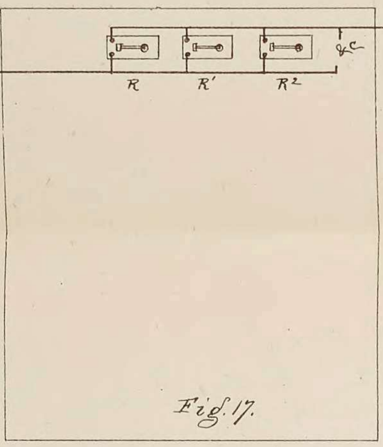


Fig. 17.

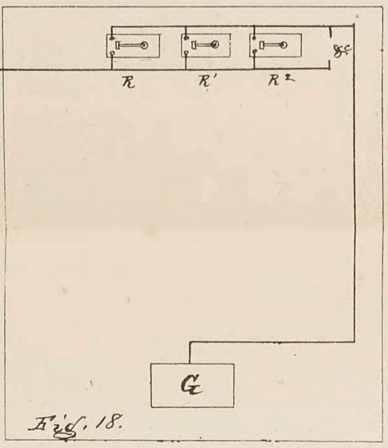


Fig. 18.

Fourth Plan

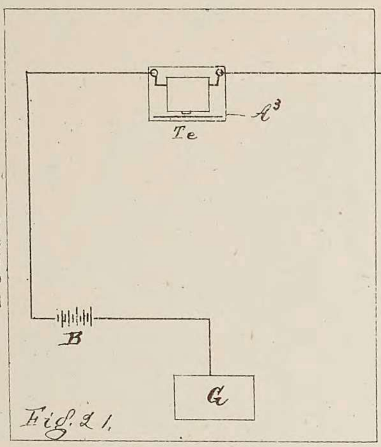
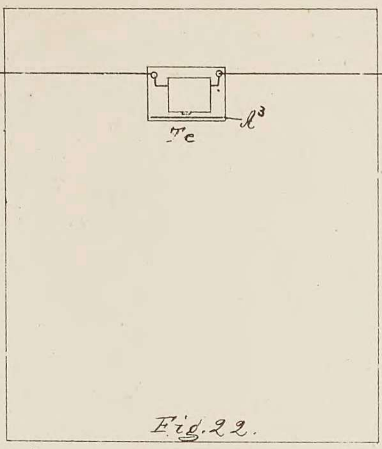


Fig. 21.



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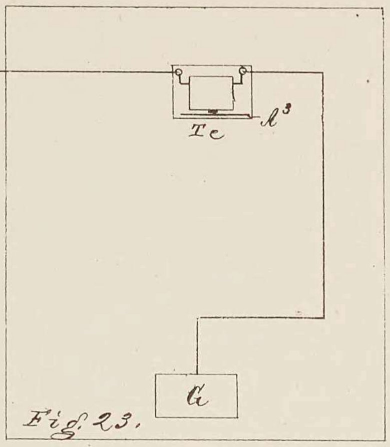
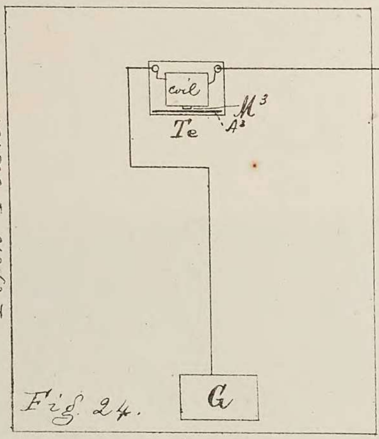


Fig. 23.

Fifth Plan.



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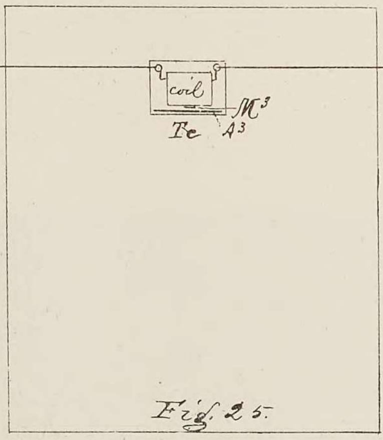

Fig. 25.

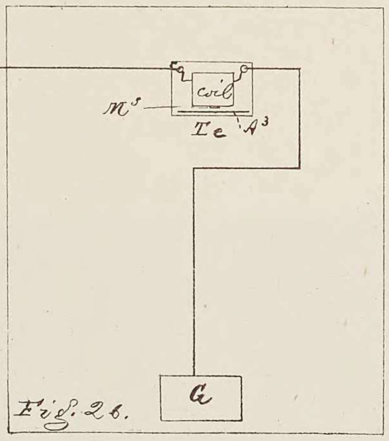

Fig. 26.

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MORGAN-BROWN'S SPECIFICATION.

(3 SHEETS)
SHEET 3.

FIG 32.

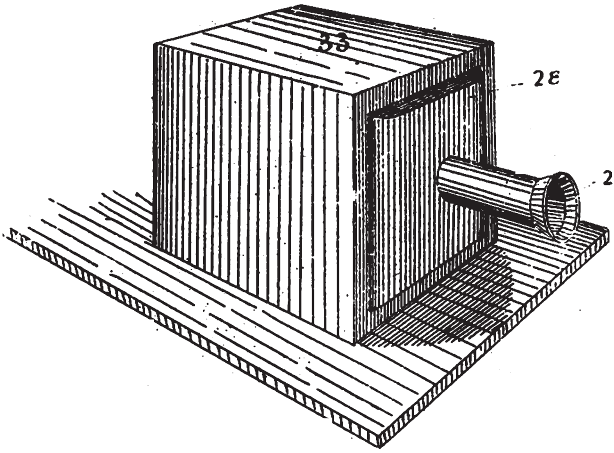
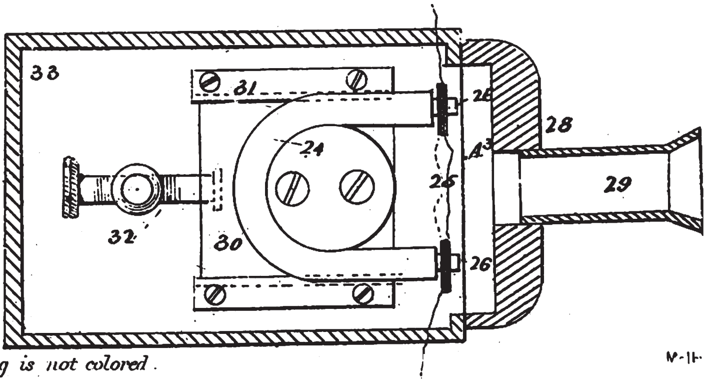


FIG 31



The filed drawing is not colored.

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Printers to the Queen's most Excellent Majesty.—1876.